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Thermal Performance Characteristics of Commercial Pre-Fabricated Metal Chimneys For Use With Oil, Wood and Gas Furnaces

FINAL REPORT

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Scientific Authority

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Thermal Performance Characteristics of Commercial Pre-Fabricated Metal Chimneys For Use with Oil, Wood and Gas Furnaces

FINAL REPORT

by

Ontario Research Foundation

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada

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SUMMARY

This report summarizes the work carried out by the Ontario Research Foundation under contract to the Canadian Combustion Research Laboratories of the Department of Energy, Mines and Resources (EMR) for Thermal Performance Evaluation of Pre-Fabricated Metal Chimneys For Use With Oil, Gas and Wood Fired Heating Systems.

A total of nineteen chimneys, consisting of nine type "A", seven type "B", one type "L", and two type "650" was tested. Thermal conductivity temperature profiles and thermal gradients at "thermal bridge" locations were determined for each chimney tested.

Tests were also undertaken to establish if condensation of the flue gas occurred during the performance tests. The information presented in this report will help researchers to better understand corrosion mechanisms which can occur in this type of heating system.

DSS/EMR Metal Chimneys Project
Final Report
ORF Contract No. 36034-82

1. INTRODUCTION

This report is the result of a project funded by the Canadian Combustion Research Laboratories of the Department of Energy, Mines and Resources for the thermal performance evaluation of nineteen representative pre-fabricated metal chimneys available in Canada.

There are a number of pre-fabricated chimney systems which are available in Canada. They are categorized in four main types" "A", "B", "L" and "650" which determine their use. The "650" is approved for high temperature applications. Types "A" and "L" are approved for use with oil fired systems and "B" is approved for gas fired appliances.

A number of Canadian manufacturers produce these chimneys. However, the thermal performance characteristics are not well established.

Under this program, nineteen representative pre-fabricated chimneys of 7" diameter were tested under simulated outdoor conditions to establish their normal performance characteristics.

2. BACKGROUND

Pre-fabricated metal chimneys are gaining widespread use in Canada. They are used in place of the conventional masonry chimney for furnaces, water heaters and fireplaces. Therefore, it is paramount that these pre-fabricated chimneys provide years of safe operation.

A major area of concern is corrosion. If the thermal performance characteristics of these chimneys allows condensation of the flue gas, corrosion of the metal chimneys will occur. This can cause a weakening of the chimney to the point where a complete structural failure may occur. These failures can lead to an unsafe or hazardous condition whereby flue gas may leak into the home.

Therefore, it is paramount for the chimneys to have a low thermal conductivity to prevent the flue gas from cooling below the dewpoint before being exhausted.

3. TEST OBJECTIVES

The objective of this program was to identify the thermal performance characteristics of pre-fabricated metal chimneys. This was accomplished by determining the temperature profile through the chimney along its entire length. From this information, and the heat loss of the flue gas, the thermal conductivity of the chimneys was determined. The program was also structured to identify thermal bridges and their associated temperature gradients. These bridges can result in cold spots within the chimney where localized condensation might occur.

Finally, analyses were undertaken to determine if any condensation occurred during steady-state performance testing of the chimney units.

4. TEST FACILITIES AND INSTRUMENTATION

A facility was built for the testing of the pre-fabricated metal chimneys as shown in Figure 1. A 6.6 mm high chimney enclosure was constructed to enclose and support the chimneys. The facility also gave a means of providing cold air on the outside walls of the chimneys. The chimney enclosure was installed under an exhaust hood connected to the building exhaust system to vent the flue gases.

The cold air (simulating outdoor environment) was supplied from a refrigeration system capable of delivering 500 cubic metres per hour of air at $-12^{o}C$. This simulated outdoor winter condition was created in order to determine if condensation would occur under cold operating

conditions. To measure condensation, a dew point sampling system was installed as shown in Figure 2. Flue gas samples were taken from three different locations along the chimney length (base, mid-point, and exit). By measuring the "dew point" temperature at these locations it was possible to determine if condensation had occurred.

Figure 3 illustrates the flue gas analysis system used in the test program. The system continuously monitored flue gas concentrations for O_2, CO and CO_2 from which combustion characteristics and flue gas mass flow rate were determined.

Thermocouple and flue gas analysis instrumentation were interfaced with a digital voltmeter and scanner which relayed the data to a Hewlett Packard desk-top computer. Dew point meter and draft reading were manually entered in the computer at selected time intervals. Software was written which enabled the computer to automatically display any operating parameter, record relevant data, process the data and provide a hard copy of the performance characteristics.

After completion of the installation, all instrumentation was calibrated and a trial test was carried out to check the facility.

5. TEST METHODOLOGY

Testing of each pre-fabricated metal chimney under evaluation was carried out in accordance with the contract requirements. The chimneys were erected in accordance with manufacturer specifications. The chimney system structure was erected from sections of nominally 17.8 cm diameter by 1 metre long to a total height of approximately 5 metres. Each chimney section was instrumented with type "J", 24-gauge thermocouple probes, as shown in Figure 4. All thermocouple junctions were

fused to prevent high contact resistance (resulting in low voltage signal). The thermocouple probes were then taped or silver soldered to the chimney walls as conditions dictated.

Class "A" and Class "L" chimney systems were tested on an oil-fired furnace and Class "B" and Class "650" standard were tested on a natural gas-fired furnace. These furnaces were operated in accordance with the appropriate CSA guidelines on draft intensity. The flue gas from these furnaces was then routed through the pre-fabricated metal chimneys under evaluation.

Each chimney was installed in an enclosure, as shown in Figure 4. The air temperature within the chimney enclosure was maintained below $0^{o}C$ to simulate an outdoor exposure. A chiller system was used to accomplish this. The cold air supply from the chiller unit entered the enclosure at the base and exited at the top. The cold air completely surrounded the outer shell of the chimney throughout the entire length.

On test start-up, the system was operated for nominally one hour to allow conditions to stabilize. Once equilibrium conditions were reached, the chimney was tested over a one and half hour test period. Test data was collected during this period and recorded with the data acquisition system.

Data collected during each test included:

* Temperature profile of the chimney walls
* Temperature profile of the flue gas
* Temperature of the cold air supplied by the chiller
* Ambient temperature

* Flue gas analysis (CO, CO_2 and O_2)

* Dew point temperature (at three locations along the chimney height)

* Fuel consumption

* Draft intensity, etc.

A copy of the software written to carry out monitoring and data analysis is given in Appendix I.

Upon completion of the test, the chimney under evaluation was disassembled and removed. A new chimney system was erected in the enclosure as described earlier and tested as outlined above. Prior to testing of the chimney system, all instrumentation used to carry out the tests was calibrated.

The data collected for each chimney system tested was then analysed and the required performance characteristics were determined.

To maintain product confidentiality, each of the pre-fabricated metal chimneys tested has been assigned an identification number which distinguishes the manufacturer. A cross-reference list is given in Appendix II which designates the manufacturers.

6. DATA ANALYSES

A number of specific calculations was carried out to qualify the performance characteristics of the pre-fabricated metal chimneys tested. The procedures used in determining these chimney parameters are discussed below.

6.1. Temperature Profile Along the Chimney Height

The temperature profile throughout the chimney length is determined from the thermocouple sensors located along the chimney height. Profiles of temperature are given for the outer surface and inner surface of the metal chimneys tested. The temperature of the flue gas (measured at the centre of the chimney) is also provided.

6.2. Thermal Conductivity

In order to derive the thermal conductivity of each chimney system evaluated, the temperature drop (Δt) of the flue gas within the effective chimney height and the flue gas mass flow rate were first calculated. The flue gas temperature differential was determined by installing calibrated temperature sensors ("thermopiles") at the inlet and outlet of each chimney tested. The flue gas mass flow was calculated from fuel consumption and the flue gas parameters (CO, CO_2, O_2 and N_2).

Once these parameters were established, the average thermal conductivity of the pre-fabricated metal chimneys was determined as outlined below.

Average Thermal Conductivity for the 4.6 m Chimney Length = Flue gas heat loss (within the chimney height)/chimney surface area (using inner diameter)

Flue Gas Heat Loss = $q = M\ Cp\ \Delta t$

where

M = flue gas mass flow

Cp = specific heat of flue gas

Δt = temperature differential of flue gas within the effective chimney length

M is calculated as follows:

M = fuel flow rate*(1+theoretical air (1+ % excess air/100))

Note: Theoretical air for natural gas and fuel oil obtained from references 1 and 2.

Theoretical air for natural gas firing
= 17.2 kg air/kg of natural gas

Theoretical air for No. 2 oil firing
= 14.5 kg air/kg of No. 2 fuel oil

Excess air is computed using the following equation:

$$\text{Excess air} = 100\left(\frac{3.76*(\%\ O2 - \%\ CO/2)}{\%\ N2 - 3.76\ (\%\ O2 - \%\ CO/2)}\right)$$

where % O2, % CO, % N2 are obtained from flue gas analyses

6.3. Specific Heat of Flue Gas

The specific heat of flue gas is derived from flue gas analyses using percentage ratios and specific heats of individual flue gas components.

6.4. Chimney Surface Area (A)

The effective surface area of the metal chimney is computed using the inner diameter and the chimney height.

7. TEST RESULTS AND OBSERVATIONS

(1) Table I summarizes the thermal performance characteristics for the chimneys tested. All thermal conductivity values are consistent for each chimney type, with one exception. One Type "A" chimney (I.D. 90601) in repeated tests, consistently shows a substantially higher thermal conductivity than the other Type "A" chimneys tested.

(2) No measurable condensation was detected in any of the chimneys tested.

(3) The thermal bridges in the Type "B" chimney systems tested are more pronounced than in Types "A", "L" and "650" standard. This is not unexpected since this type has no insulation between the inner and outer walls.

(4) Air leakage was detected in one of the Type "A" chimneys tested (I.D. 90601). There was no visible defect in the chimney which would cause this air leakage. If the design of the unit is such that air leakage always occurs, this could possible cause the flue gas to drop below the "dew point" which may promote corrosion of metal surfaces.

8. RECOMMENDATIONS

Although no condensation occurred during the steady-state testing of the chimney systems during this program, it is recommended that selected types of chimneys be tested under furnace cycling conditions to determine if condensation occurs under this mode of operation. The study should also include analyses to determine what potential corrosion mechanisms occur.

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17th October 1983

TABLE I

SUMMARY OF TEST RESULTS

	Chimney Identification	Average Thermal Conductivity $W/m^2/^oC$
TYPE A	90901	3.2
	90301	3.3
	90701	3.0
	90601	6.1
	90201	3.0
	90202	2.8
	90801	3.4
	90402	3.3
	90400	3.5
TYPE B	90101	3.9
	90501	6.6
	90302	4.2
	90702	4.0
	90602	5.9
	90802	6.3
	90403	6.3
TYPE L	90303	4.4
650 STANDARD	90803*	2.1
	90404	1.8

*six inch diameter chimney

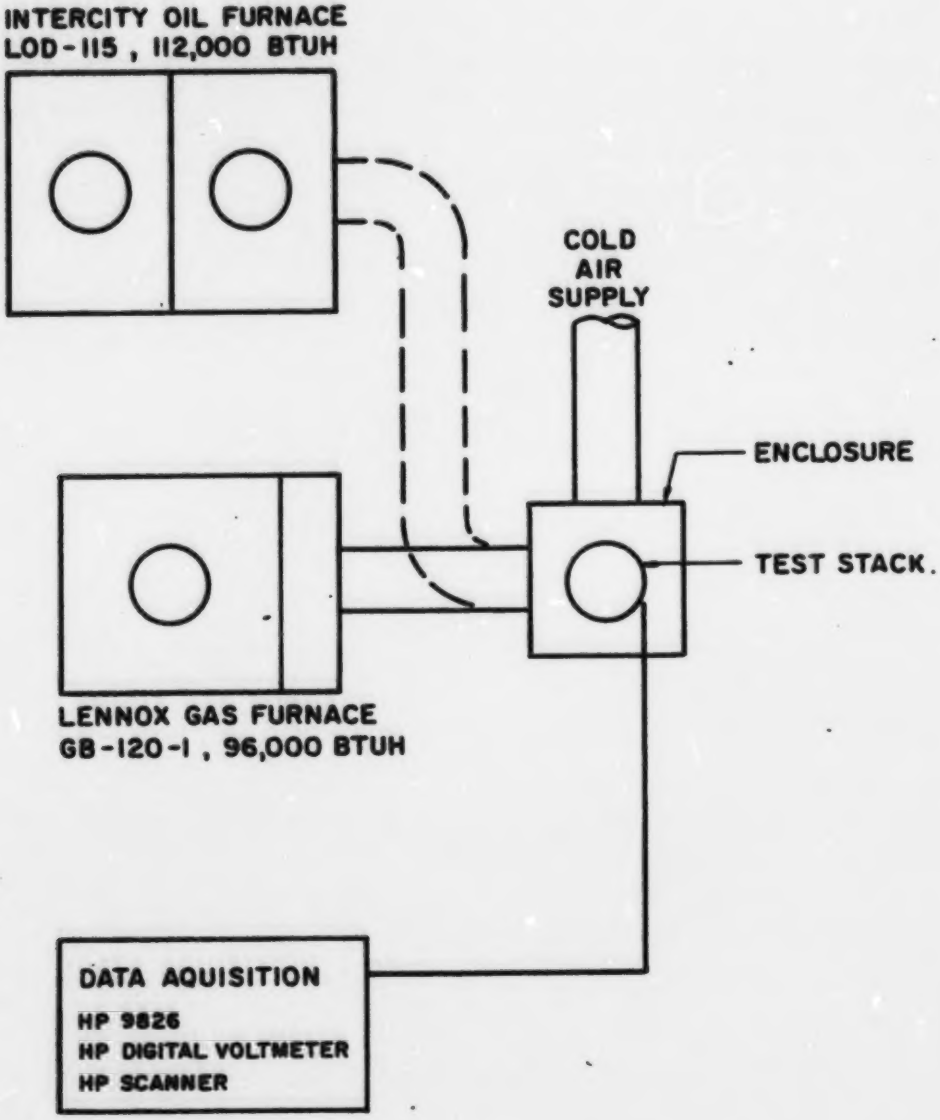


FIG. 1 PRE-FABRICATED METAL CHIMNEY TEST FACILITY

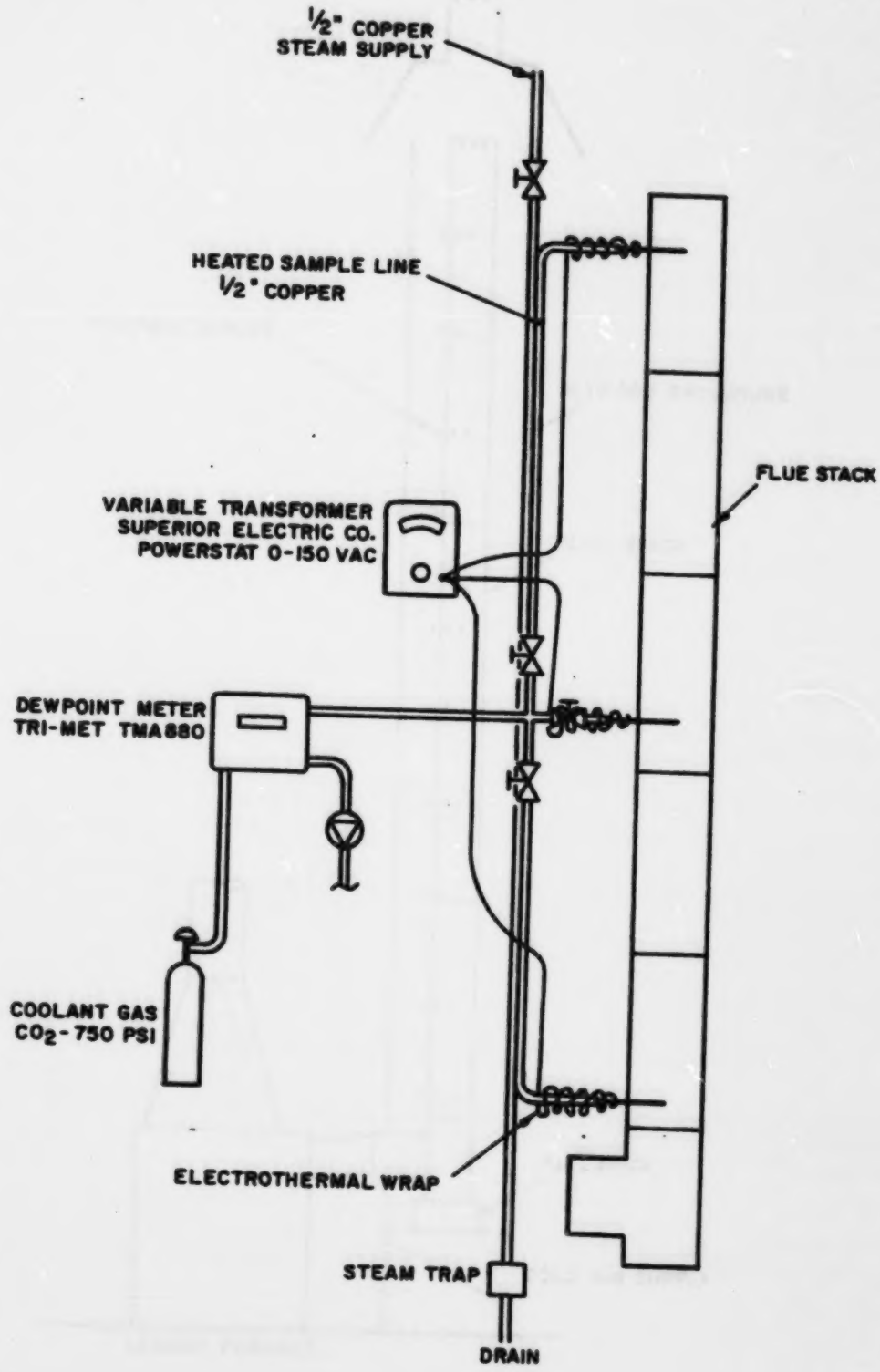


FIG. 2 FLUE GAS DEW POINT MEASUREMENT.

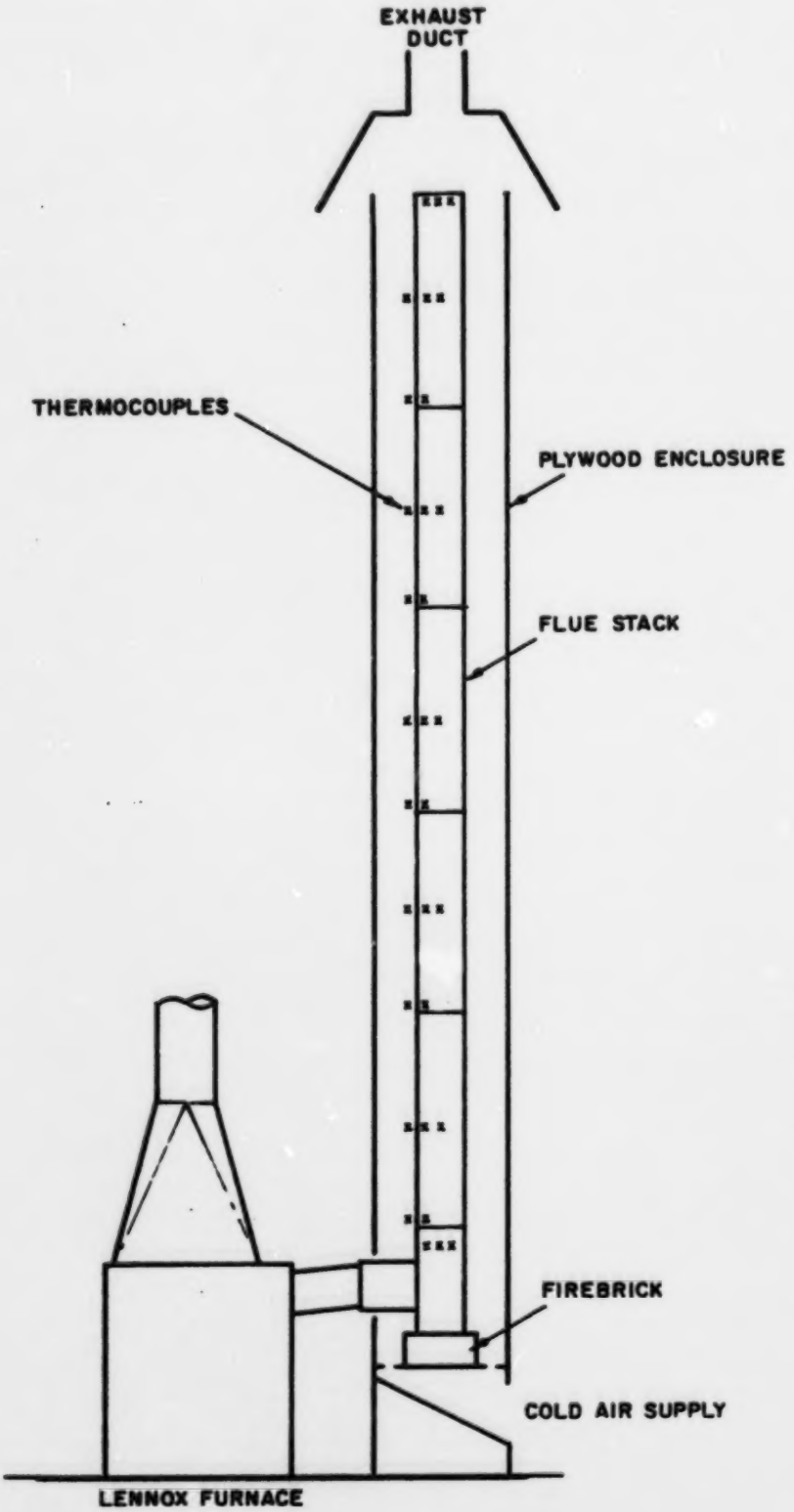


FIG. 3 CHIMNEY TEST FACILITY LAYOUT

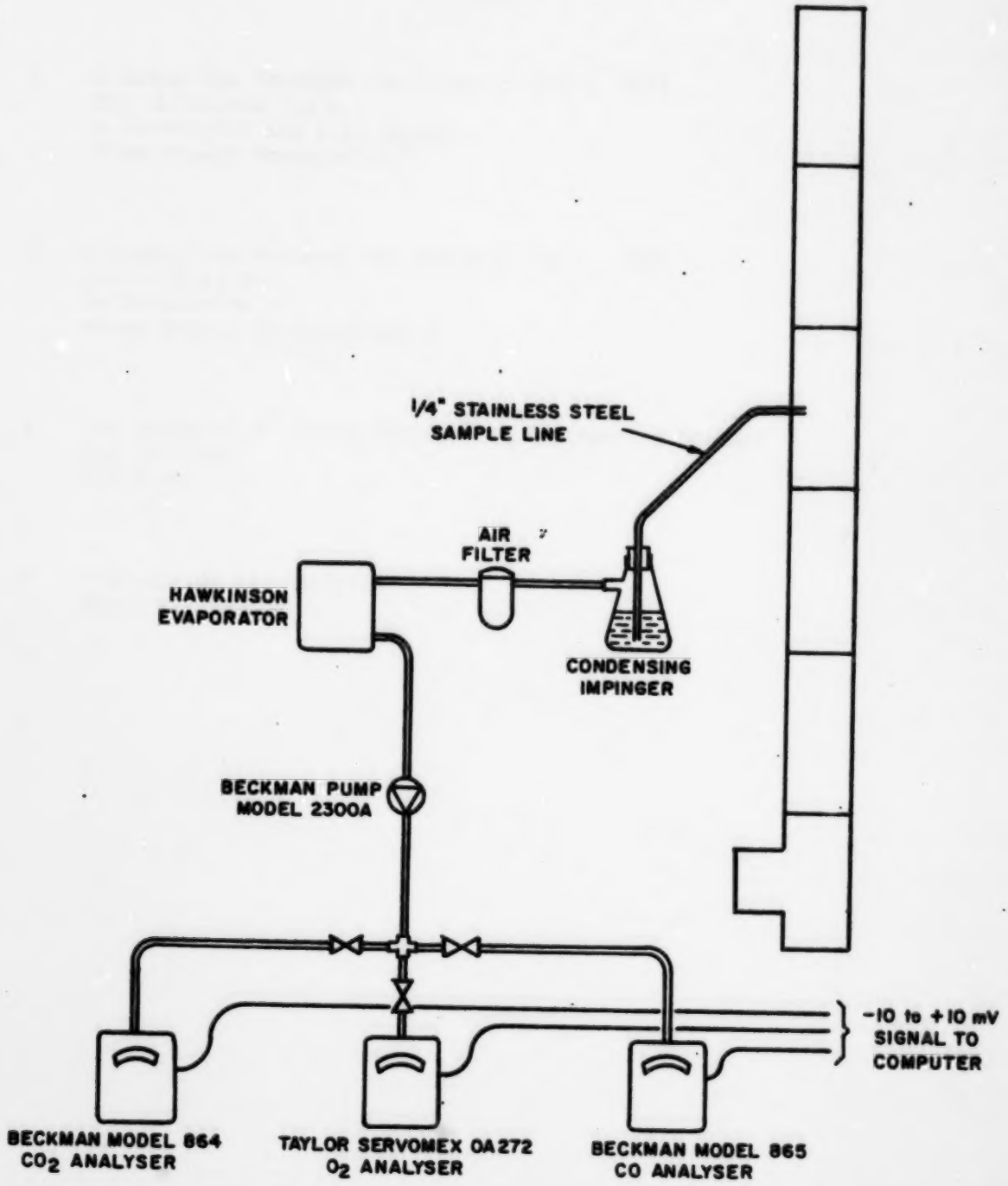


FIG. 4 FLUE GAS ANALYSIS SYSTEM

REFERENCES

1. A Combustion Handbook For Canadian Fuels, 1973
Vol. 2/Gaseous Fuels
by Friederich and C.S. Hayden
Mines Branch Monograph 879

2. A Combustion Handbook for Canadian Fuels, 1969
Vol. 1/Fuel Oil
by Friederich
Mines Branch Monograph 877

3. CRC Handbook of Tables For Applied Engineering Science
2nd Edition
CRC Press

4. TransCanada Gas Analysis
April 21, 1982

APPENDIX I

SOFTWARE PROGRAM DEVELOPED FOR DATA ACQUISITION AND ANALYSES

```
! PROGRAM NAME IS "CHIMNEY" AND THE DATA FILE     IS "DATTA"
!
! THIS PROGRAM IS DESIGNED TO COLLECT. STORE        AND MANIPULATE TEST DATA
!
! PROGRAM DEVELOPED BY BRIAN BUTTERS
! LAST UPDATE MARCH 15, 1983
!
! INITIALIZING DIMENSIONS AND DATA FILE
!
PRINTER IS 1
 DIM Tbuffer(60),Tdata(160,60),Tbuf(60),Tb(60),X(14)
 ! DETERMINING LAST FILE ENTERED WHICH IS            STORED IN Tdata(1,1)
 ASSIGN @File TO "DATTA"
 ENTER @File,1;Tbuf(*)
 Recn=Tbuf(1)
 FOR I=2 TO Recn
 PRINT I
   ENTER @File,I;Tbuf(*)
   FOR J=0 TO 60
     Tdata(I,J)=Tbuf(J)
   NEXT J
 NEXT I
 !
 GOTO 60
 Recn=1
   Recn=Recn+1
 !
 !    *** MENUE ***
 !
   PRINT "NEXT RECORD TO BE STORED IS ",Recn
   PRINT " "
   PRINT " "
   PRINT "1  SCAN AND DISPLAY DATA                ENTER 1"
   PRINT " "
   PRINT "2  STORE DISPLAYED DATA                 ENTER 2"
   PRINT " "
   PRINT "3  PRINT DESIRED RECORD (1 TO 150)      ENTER 3"
   PRINT " "
   PRINT "4  DISPLAY STORED DATA                  ENTER 4"
   PRINT " "
   PRINT "5"
 PRINT " "
 PRINT "6"
 PRINT " "
   PRINT "7  DELETE LAST RECORD ENTERED           ENTER 7"
   PRINT " "
   PRINT "8  INITIALIZE DATA FILE                 ENTER 8"
   PRINT " "
   PRINT "9  TO STOP                              ENTER 9"
 INPUT "INPUT OPTION",Choice
 DISP "EXECUTING OPTION ",Choice
 !
 SELECT Choice
 !
 CASE 1
 !  THIS SECTION OF THE PROGRAM SCANS AND RET         RIVES DATA. STORES IT
IN A BUFFER
   CLEAR 709 !THIS INITIALIZES THE SCANNER
   CLEAR 722 !THIS INITIALIZES THE DVM
   OUTPUT 722:"F1R1T4Z1FLOW1STI"
   OUTPUT 709:"AC19"
```

```
1010    WAIT .1
1012    TRIGGER 722
1013    ENTER 722;Refj
1014    Refj=Refj*10
1015    FOR I=1 TO 18
1016      IF I=7 THEN I=I+3
1018      Tb(I)=Tbuffer(I)
1019      OUTPUT 709 USING "K";"AC",I
1020      WAIT .1
1021      TRIGGER 722
1022      ENTER 722;Tbuffer(I)
1023      Tbuffer(I)=FNJ(Tbuffer(I))+Refj
1024      PRINT USING "DD.6D.DD.6D.DD.K";I,Tbuffer(I),Tb(I)," DEG C"
1025      NEXT I
1026      OUTPUT 709;"AC39"
1027      WAIT .1
1028   TRIGGER 722
1029   ENTER 722;Refj
1030   Refj=Refj*10
1031   FOR I=20 TO 38
1041      Tb(I)=Tbuffer(I)
1051      OUTPUT 709 USING "K";"AC",I
1052      WAIT .1
1061      TRIGGER 722
1071      ENTER 722;Tbuffer(I)
1072      IF (I<36) THEN GOTO 1090
1073      IF (I<>36) THEN GOTO 1078
1074      Tbuffer(36)=Tbuffer(36)*2500
1075      PRINT USING "DD.6D.DD.6D.DD.K";I,Tbuffer(I),Tb(I)," %O2"
1076        GOTO 1101
1078      IF (I<>37) THEN GOTO 1087
1083        Tbuffer(37)=Tbuffer(37)*10
1084        PRINT USING "DD.6D.DD.6D.DD.K";I,Tbuffer(I),Tb(I)," %CO"
1086        GOTO 1101
1087        Tbuffer(38)=Tbuffer(38)*1000
1088        PRINT USING "DD.6D.DD.6D.DD.K";I,Tbuffer(38),Tb(38)," %CO2"
1089        GOTO 1101
1090      Tbuffer(I)=FNJ(Tbuffer(I))+Refj
1091      PRINT USING "DD.6D.DD.6D.DD.K";I,Tbuffer(I),Tb(I)," DEG C"
1101      NEXT I
1111 ! 20 TO 29 WILL BE JOINT TC
1121 ! 30 WILL BE OUT GAS TEMP
1131 ! 31 WILL BE IN GAS TEMP
1141 ! 32,33,34 WILL BE COLD AIR PROFILE
1142 ! 35 WILL BE AMBIANT
1151 ! 36=O2, 37=CO, 38=CO2
1500 ! ENTERING AUX. DATA
1501 ! 55 IS FUEL CONSUMPTION RATE
1502 ! 54 IS DRAFT PRESSURE
1503 ! 53 IS EMPTY
1510 INPUT "ENTER AUX. DATA Y OR N ",Aa$
1520 SELECT Aa$
1530   CASE "Y"
1531   INPUT "PRODUCT # ",Tbuffer(59)
1532   INPUT "READING # ",Tbuffer(58)
1534   INPUT "FLUE TYPE, 1=A,2=B,3=L,4=650STD ",Tbuffer(57)
1535   INPUT "FUEL TYPE, 1=GAS,2=OIL ",Tbuffer(56)
1536   SELECT Tbuffer(56)
1537   CASE 1
1539     INPUT "HOURLY GAS CONSUMPTION RATE ",Tbuffer(55)
1542     INPUT "GAS TEMPERATURE",Gast
```

```
1543      INPUT "GAS PRESURE ",Gasp
1544      Tbuffer(55)=Tbuffer(55)/3600*(.07616*.576*(519/(Gast+459))*(407+Gasp)/4
07*.4535924)
1545      CASE 2
1546      !  OIL PUMP CALIBRATED AT 2.585 KG/H
1548      Tbuffer(55)=.000718
1549    END SELECT
1550    INPUT "TOP DEW POINT READING",Tbuffer(19)
1551    Tbuffer(19)=(Tbuffer(19)-32)/9*5
1553    INPUT "MIDDLE DEW POINT READING",Tbuffer(51)
1554    Tbuffer(51)=(Tbuffer(51)-32)/9*5
1555    INPUT "BOTTOM DEW POINT READING",Tbuffer(50)
1556    Tbuffer(50)=(Tbuffer(50)-32)/9*5
1557    INPUT "CHIMNEY DRAFT       ",Tbuffer(54)
1558    Tbuffer(54)=Tbuffer(54)*101.325/407*1000
1559    END SELECT
1999 !
2000 CASE 202
2005 !THIS SECTION OF THE PROGRAM STORES THE              DISPLAYED DATA AS A PERM
INATE RECORD
2006 !   RECN IS THE RECORD NUMBER OF THE DATA              BEING ENTERED
2015    FOR I=0 TO 60
2020      Tdata(Recn,I)=Tbuffer(I)
2025    NEXT I
2035    Tdata(Recn,60)=Recn
2900    ASSIGN @File TO "DATTA"
2901    Tdata(1,1)=Recn
2903    FOR I=1 TO Recn
2904      FOR J=0 TO 60
2905      Tbuffer(J)=Tdata(I,J)
2906      NEXT J
2910    OUTPUT @File,I;Tbuffer(*),END
2920    NEXT I
2930    PRINT "RECORD # ",Recn," HAS BEEN STORED"
2940    Recn=Recn+1
2950    DISP "HIT CONTINUE"
2960    PAUSE
2999 !
3000 CASE 3
3001 ! THIS SECTION OF THE PROGRAM PRINTS A              DESIRED RECORD
3009   PRINT " "
3010   INPUT "INPUT RECORD NUMBER ",Rec
3012   PRINTER IS 701
3013   PRINT "THERMAL PERFORMANCE CHARACTERISTICS OF PREFAB METAL CHIMNEYS"
3014   PRINT "  MANUFACTURE # ",Tdata(Rec,59),"RECORD # ",Tdata(Rec,60),"READING
",Tdata(Rec,58)
3015   PRINT " "
3017   SELECT Tdata(Rec,57)
3018     CASE 1
3019     PRINT "CHIMNEY IS TYPE 'A'"
3020     CASE 2
3021     PRINT "CHIMNEY IS TYPE 'B'"
3022     CASE 3
3023     PRINT "CHIMNEY IS TYPE 'L'"
3024     CASE 4
3025     PRINT "CHIMNEY IS TYPE '650 STD'"
3026     END SELECT
3027     SELECT Tdata(Rec,56)
3028     CASE 1
3029     PRINT "CHIMNEY TESTED ON GAS"
3031     Cair=17.276
```

```
3032    Molfrac=2
3034    CASE 2
3035    PRINT "CHIMNEY TESTED ON OIL"
3036    Cair=14.49
3037    Molfrac=3
3039    END SELECT
3040  PRINT " "
3041  PRINT "CHIMNEY TEMPERATURE PROFILE"
3042  PRINT "    OUTER    INNER    CENTER   DISTANCE TO TOP"
3043  Dist=18/39.6
3045  FOR I=1 TO 6
3046  IF Tdata(Rec,(I*3))=0 THEN GOTO 3051
3048  PRINT USING "6D.DD,6D.DD,6D.DD";Tdata(Rec,(I*3-2)),Tdata(Rec,(I*3-1)),Tdat
a(Rec,(I*3)),Dist
3049  Dist=36/39.6+Dist
3051    NEXT I
3052    PRINT " "
3053  PRINT USING "K,6D.DD";"EXHAUST FLUE GAS TEMPERATURE ",Tdata(Rec,30),"  C"
3054  PRINT USING "K,6D.DD";"INTAKE FLUE GAS TEMPERATURE  ",Tdata(Rec,31),"  C"
3055  PRINT "ENCLOSURE TEMPERATURE PROFILE"
3056  PRINT USING "K,6D.DD";"TOP     ",Tdata(Rec,32)," C"
3057  PRINT USING "K,6D.DD";"MIDDLE  ",Tdata(Rec,33)," C"
3058  PRINT USING "K,6D.DD";"BOTTOM  ",Tdata(Rec,34)," C"
3059  PRINT USING "K,6D.DD";"AMBIENT TEMPERATURE          ",Tdata(Rec,35),"  C"
3060  PRINT USING "K,6D.DD";"THE O2 CONCENTRATION IS      ",Tdata(Rec,36),"  %"
3061  Coppm=Tdata(Rec,37)*10^4
3062  PRINT USING "K,6D.DD";"THE CO CONCENTRATION IS      ",Coppm,"  PPM"
3063  PRINT USING "K,6D.DD";"THE CO2 CONCENTRATION IS     ",Tdata(Rec,38),"  %"
3064  PRINT USING "K,6D.DD";"DRAFT PRESSURE               ",Tdata(Rec,54),"  Pa"
3065  Fuelc=Tdata(Rec,55)*1000
3066  PRINT USING "K,6D.DD";"FUEL CONSUMPTION RATE        ",Fuelc,"  gm/s"
3067  Ddd=3.76*(Tdata(Rec,36)-Tdata(Rec,37)/2)
3068  Eair=100*Ddd/((100-Tdata(Rec,36)-Tdata(Rec,37)-Tdata(Rec,38))-Ddd)
3069  PRINT USING "K,6D.DD";"THE EXCESS AIR IS            ",Eair,"  %"
3070  ! CP CALCULATION
3071  ! UNIT VOLUME DRY
3072  O2=Tdata(Rec,36)/100
3073  Co=Tdata(Rec,37)/100
3074  Co2=Tdata(Rec,38)/100
3075  N2=1-O2-Co-Co2
3076  H2O=Co2*Molfrac
3077  ! UNIT MASS (WET)
3078  Tm=O2*32+Co*28+Co2*44+N2*28+H2o*18
3079  ! PROPORTION CP
3080  O2cp=O2*32/Tm*.917
3081  Cocp=Co*28/Tm*1.045
3082  Co2cp=Co2*44/Tm*.876
3083  N2cp=N2*28/Tm*1.045
3084  H2ocp=H2o*18/Tm*1.867
3085  ! CP TOTAL (KJ/KG/K) OF WET FLUE GAS
3086  Cp=O2cp+Cocp+Co2cp+N2cp+H2ocp
3087  PRINT USING "K,6D.DD";"SPECIFIC HEAT                ",Cp,"  KJ/KG/K"
3088  ! MASS FLOW RATE
3089  Mfr=Tdata(Rec,55)*(1+Cair+(Cair*(Eair/100)))
3090  Mfrr=Mfr*1000
3091  PRINT USING "K,6D.DD";"MASS FLOW RATE               ",Mfrr,"  gm/s"
3092  ! FLUE HEAT LOSS
3093  Fhl=Mfr*Cp*(Tdata(Rec,31)-Tdata(Rec,30))
3094  PRINT USING "K,6D.DD";"FLUE HEAT LOSS               ",Fhl,"  KW"
3095  ! THERMAL CONDUCTIVITY
3096  Ts=(Tdata(Rec,1)+Tdata(Rec,4)+Tdata(Rec,10)+Tdata(Rec,13)+Tdata(Rec,16))/5
```

```
3097  Ti=(Tdata(Rec,2)+Tdata(Rec,5)+Tdata(Rec,22)+Tdata(Rec,14)+Tdata(Rec,17))/5
3098  U=Fh1/2.524/(Ti-Ts)*1000
3099  PRINT USING "K,6D.DD":"OVERALL THERMAL CONDUCTIVITY ",U,"  WATTS/M2/C"
3100  PRINT " "
3101  PRINT "HEAT LOSS PER SECTION "
3102  PRINT "SEC   W/M2   DELTA T    WATTS"
3103  Ii=0
3104  FOR I=1 TO 6
3105  Dt=(Tdata(Rec,(3*I-1))-Tdata(Rec,(3*I-2)))
3106  Qq=U*Dt
3107  Ii=Ii+1
3108  IF Qq=0 THEN Ii=Ii-1
3109  IF Qq=0 THEN GOTO 3112
3110  Secloss=Qq*3.14*7*36/39.6/39.6
3111  PRINT USING "K,6D.DD,6D.DD,6D.DD";Ii,Qq,Dt,Secloss
3112  NEXT I
3113  PRINT " "
3114  PRINT "THERMAL BRIDGES AT CONNECTING JOINTS 'DEGREES C'"
3115  PRINT "SEC  INNER    OUTER    DELTA T"
3116  FOR I=1 TO 5
3117  Dt=Tdata(Rec,(18+2*I))-Tdata(Rec,(19+2*I))
3118  PRINT USING "K,6D.DD,6D.DD,6D.DD":I,Tdata(Rec,(18+2*I)),Tdata(Rec,(19+2*I)
),Dt
3119  NEXT I
3120  PRINT " "
3121  PRINT "DEW POINT READINGS 'DEGREES C'"
3122  PRINT USING "K,6D.DD":"TOP    ",Tdata(Rec,19)
3123  PRINT USING "K,6D.DD":"MIDDLE ",Tdata(Rec,51)
3124  PRINT USING "K,6D.DD":"BOTTOM ",Tdata(Rec,50)
3125  PRINTER IS 1
4000 CASE 4
4010 REM THIS SECTION OF THE PROGRAM IS TO DIS-        PLAY PREVIOUSLY STORED DA
TA
4020 INPUT "DESIRED RECORD # ",Recnum
4021 PRINT "DISPLAYING RECORD # ",Recnum
4022 FOR I=1 TO 15
4023 PRINT Tdata(Recnum,(I*4-3)),Tdata(Recnum,(I*4-2)),Tdata(Recnum,(I*4-1)),Tda
(Recnum,(I*4))
4024 NEXT I
4025 PRINT " "
4027 DISP "HIT CONTINUE"
4030 PAUSE
5000 CASE 505
5010 Tdata(69,9)=(163.7+154.18)/2
5020 Tdata(68,9)=(163.53+154.09)/2
5030 Tdata(70,9)=(154.29+163.35)/2
7000 CASE 707
7010   Recn=Recn-1
7020   Tdata(1,1)=Recn
8000 CASE 8
8010   GOTO 5
9000 CASE 9
9001   ASSIGN @File TO *
9002   DISP "PROGRAM ENDED"
9005   GOTO 10000
9995 END SELECT
9999 GOTO 100
10000 END
10010 DEF FNJ(A)
10020 C1=-4.8868252E-2
10021 C2=1.987314503E+4
```

```
10022 C3=-2.186145353+5
10023 C4=1.156919978+7
10030 C5=-2.649175314E+8
10040 C6=2.018441314+9
10050 RETURN C1+A*(C2+A*(C3+A*(C4+A*(C5+C6*A))))
10060 FNEND
```

APPENDIX II

CROSS REFERENCE LIST
OF MANUFACTURERS AND CHIMNEY IDENTIFICATION

CROSS REFERENCE LIST
OF
MANUFACTURERS AND CHIMNEY IDENTIFICATION

MANUFACTURER	VENT TYPE	I.D.
DON PARK INC.	B	90101
OLIVER-MACLEOD LTD.	A	90201
	Squ. A	90202
JAMES A. RYDER MFG. LTD.	A	90301
	B	90302
	L	90303
SELKIRK METALBESTOS	*A-CC	90400
	A-SS	90402
	B	90403
	650 STD	90404
ECCO HEATING PRODUCTS	B	90501
METAL-PAC MFG.	A	90601
	B	90602
MADISON INDUSTRIES LTD.	A	90701
	B	90702
SECURITY CHIMNEYS LTD.	A	90801
	B	90802
	650 STD	90803
G S W INC.	A	90901

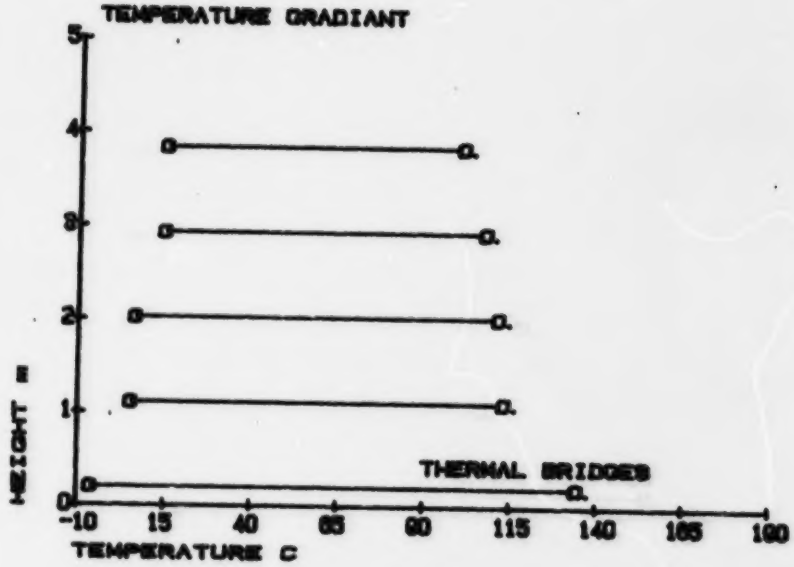
*CHIMNEY REQUESTED BY SCIENTIFIC AUTHORITY

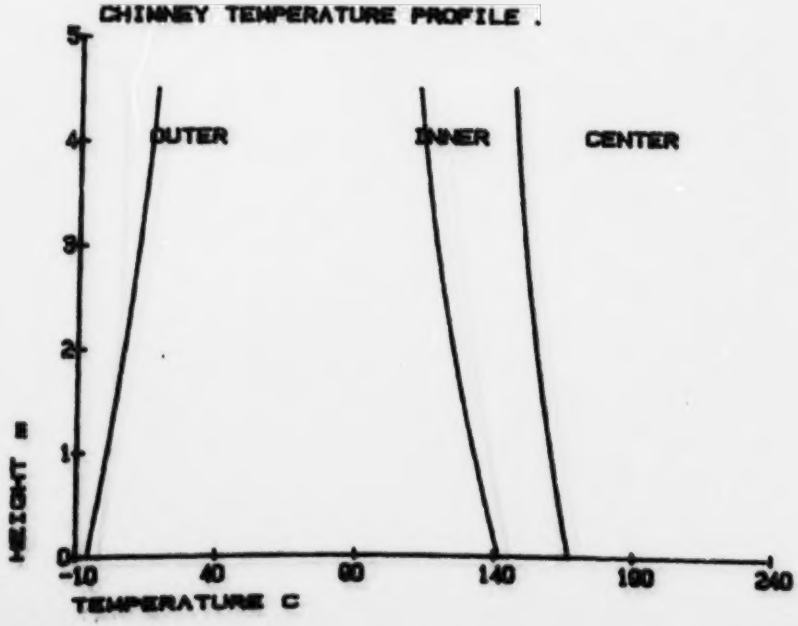
APPENDIX III

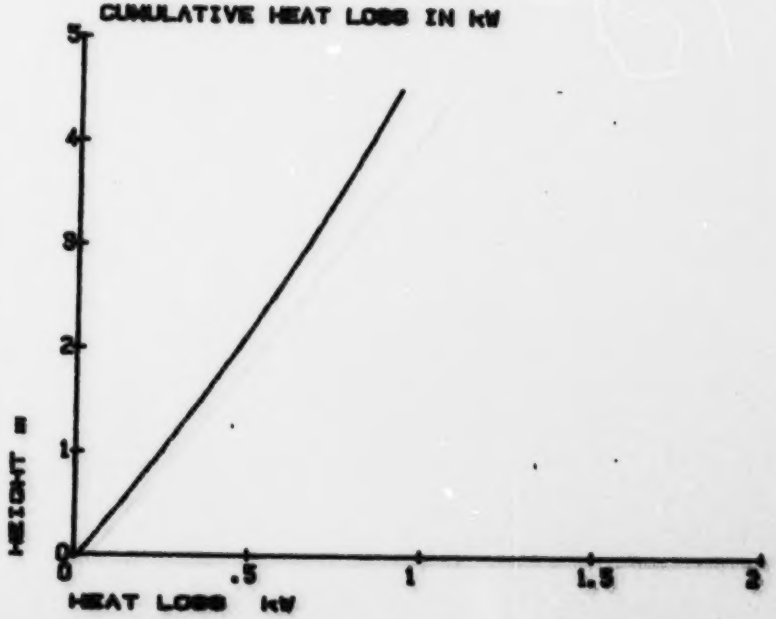
THERMAL PERFORMANCE CHARACTERISTICS OF PRE-FABRICATED METAL CHIMNEYS TESTED

THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90901..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	158 C.
AVG. THERMAL CONDUCTIVITY	3.17 W/m2/C.
MASS FLOW RATE:	85 gm/s.
TOTAL HEAT LOSS:	908 WATTS.

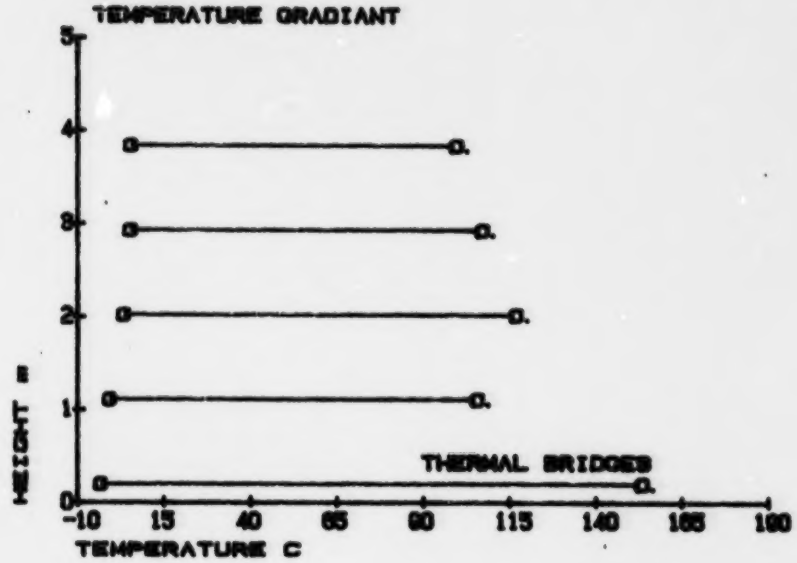


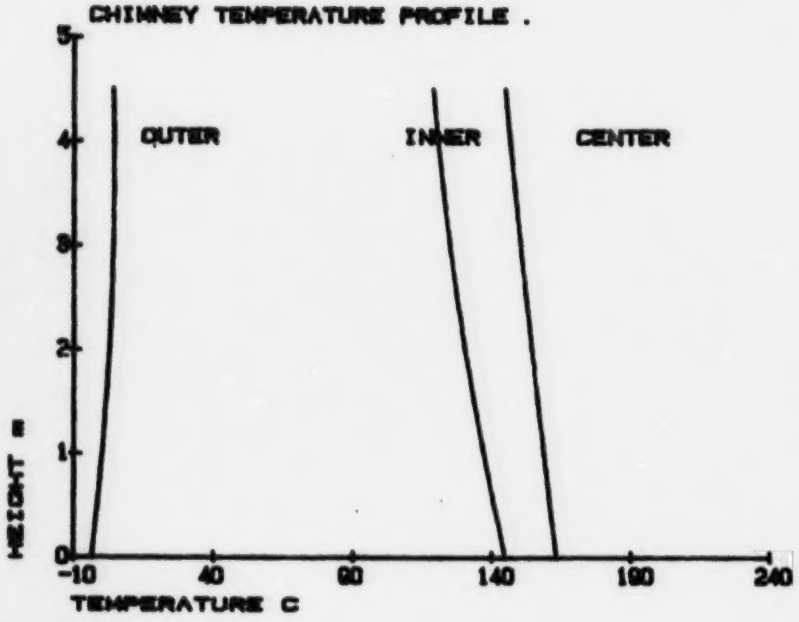


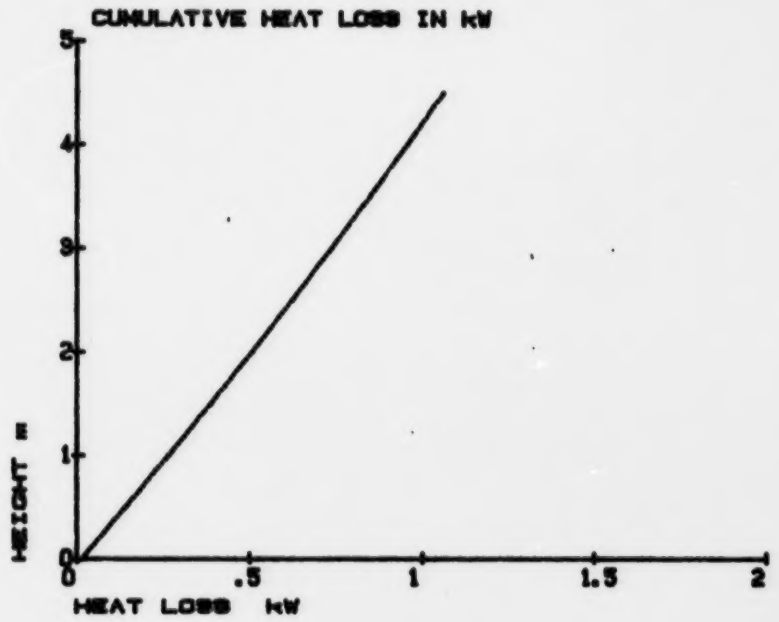


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	SOSO1..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	155 C.
AVG. THERMAL CONDUCTIVITY	8.82 W/m2/C.
MASS FLOW RATE:	41 gm/s.
TOTAL HEAT LOSS:	1091 WATTS.

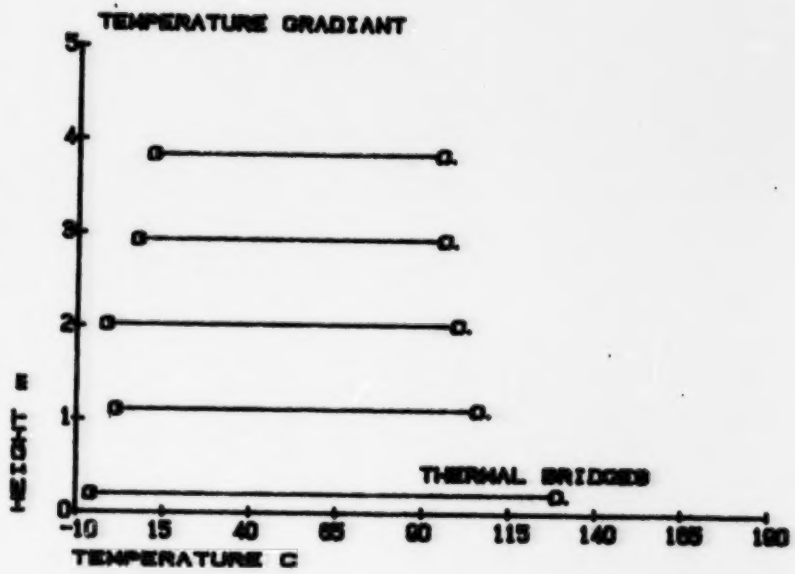


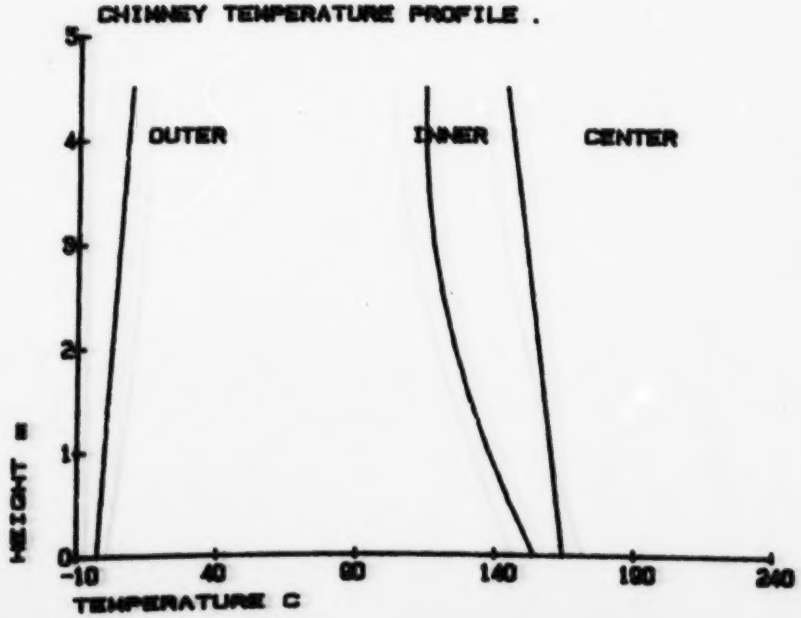


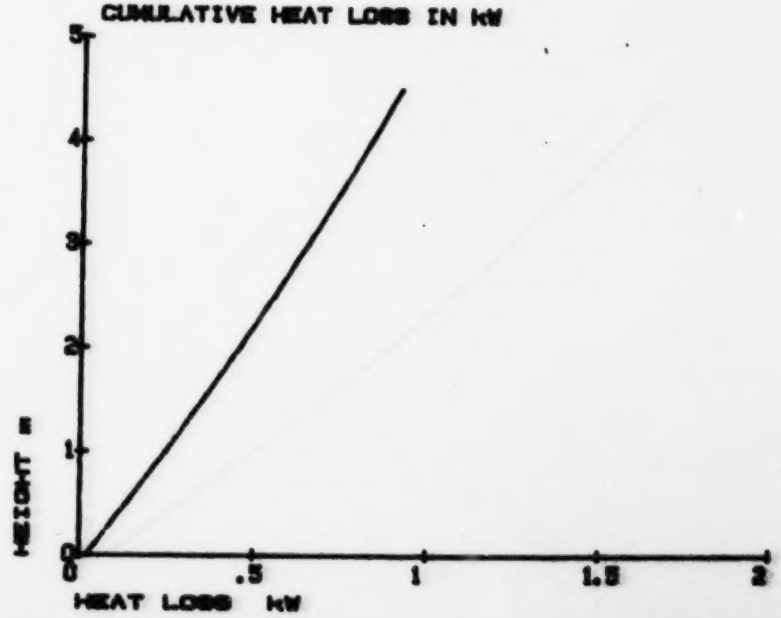


.THERMAL PERFORMANCE CHARACTERISTICS.
OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	90701..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	158 C.
AVG. THERMAL CONDUCTIVITY	2.68 W/m2/C.
MASS FLOW RATE.	87 gm/s.
TOTAL HEAT LOSS.	882 WATTS.

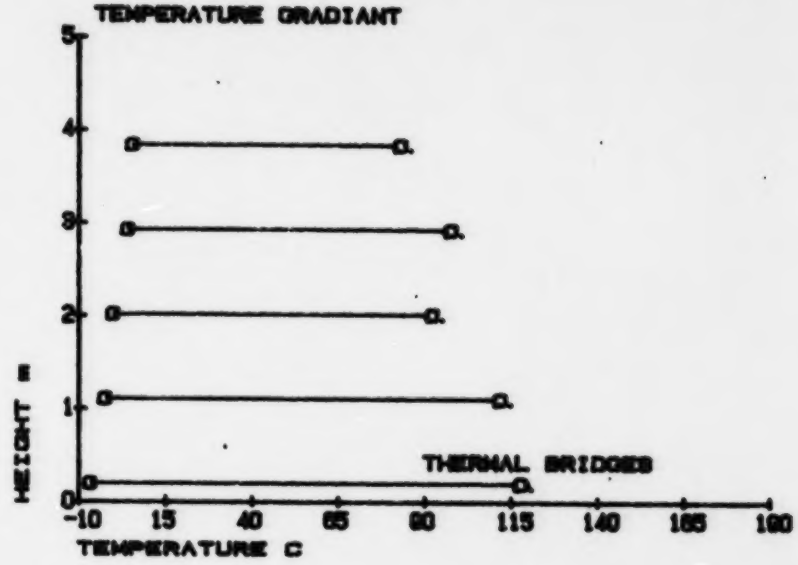


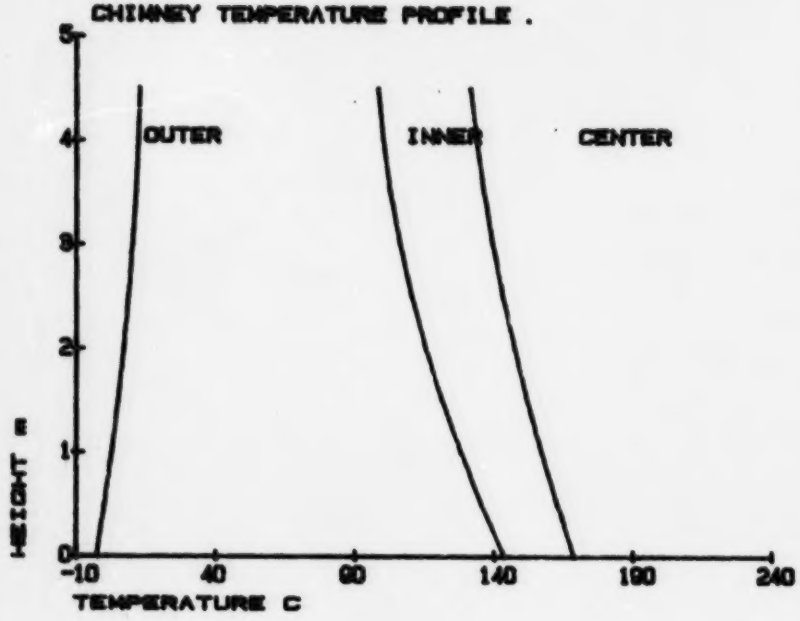


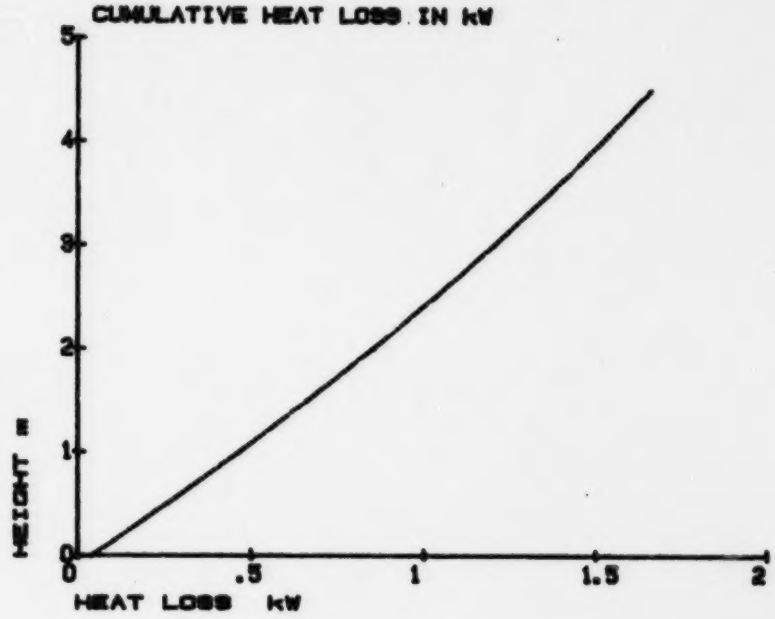


THERMAL PERFORMANCE CHARACTERISTICS.
OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	SOSOI..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	148 C.
AVG. THERMAL CONDUCTIVITY	6.12 W/m2/C.
MASS FLOW RATE.	41 gm/s.
TOTAL HEAT LOSS.	1811 WATTS.

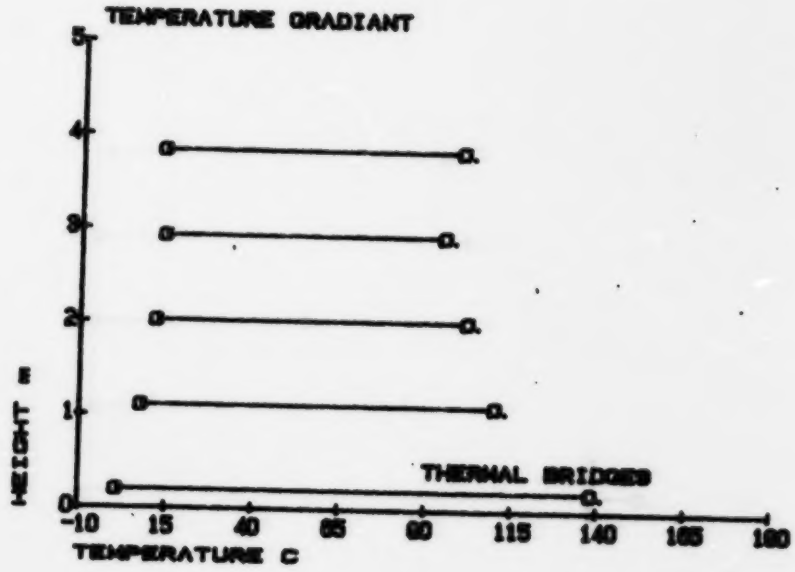


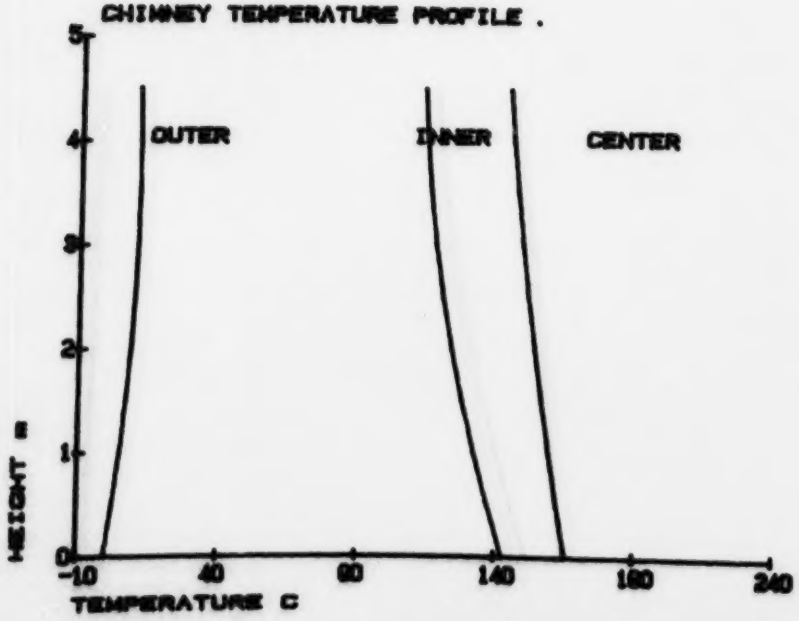


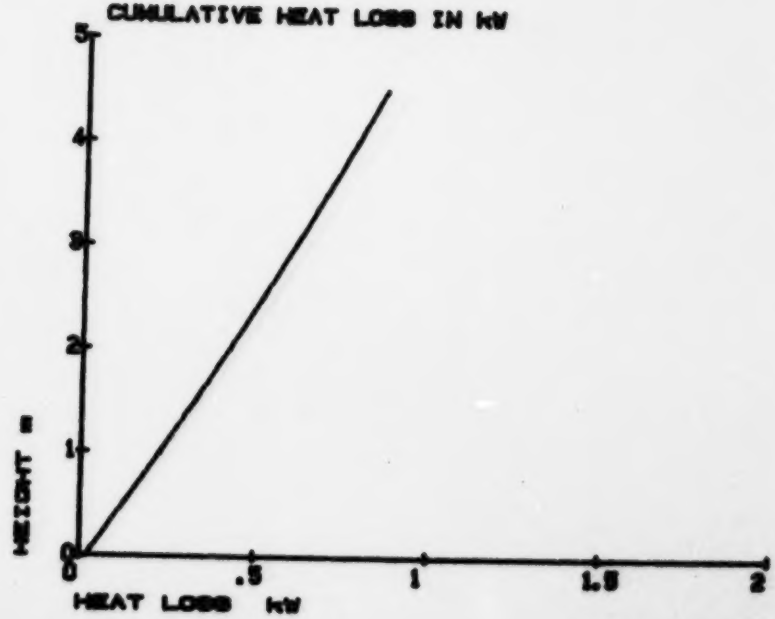


THERMAL PERFORMANCE CHARACTERISTICS.
OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	90201..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	159 C.
AVG. THERMAL CONDUCTIVITY	2.99 W/m2/C.
MASS FLOW RATE.	96 gm/s.
TOTAL HEAT LOSS.	826 WATTS.

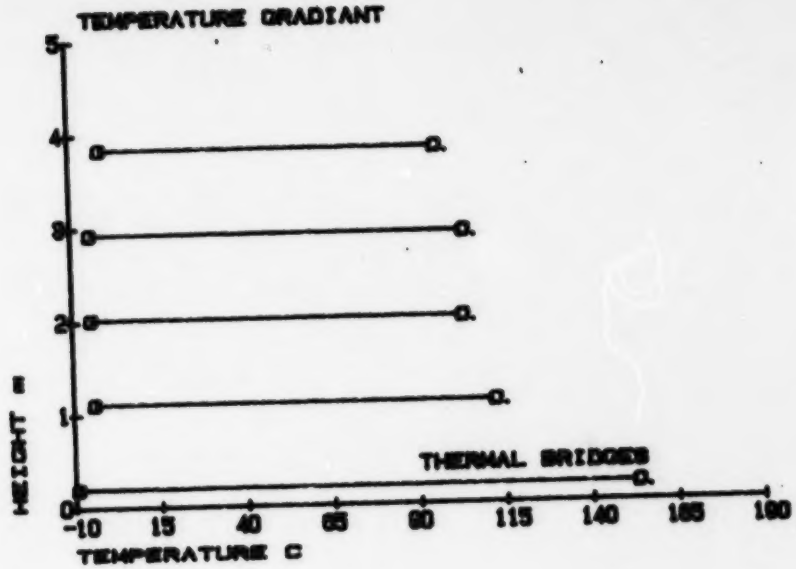


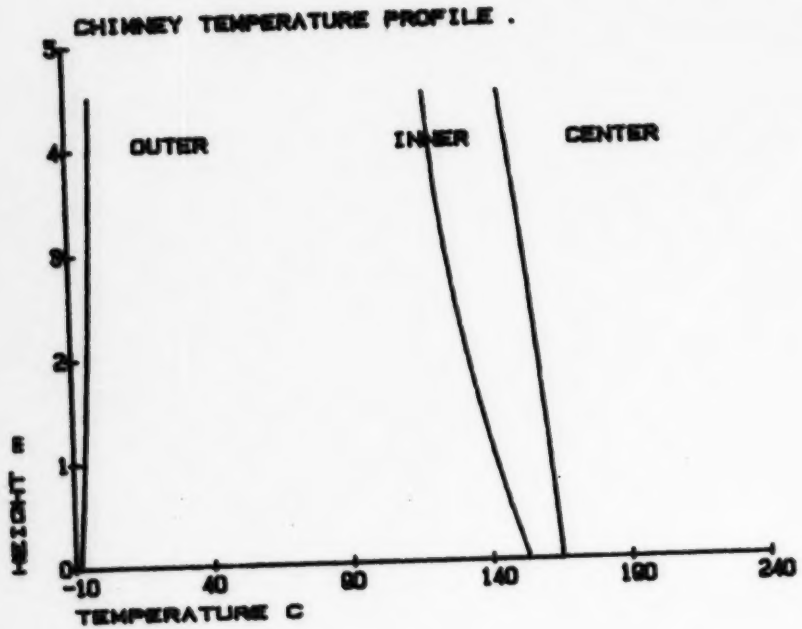


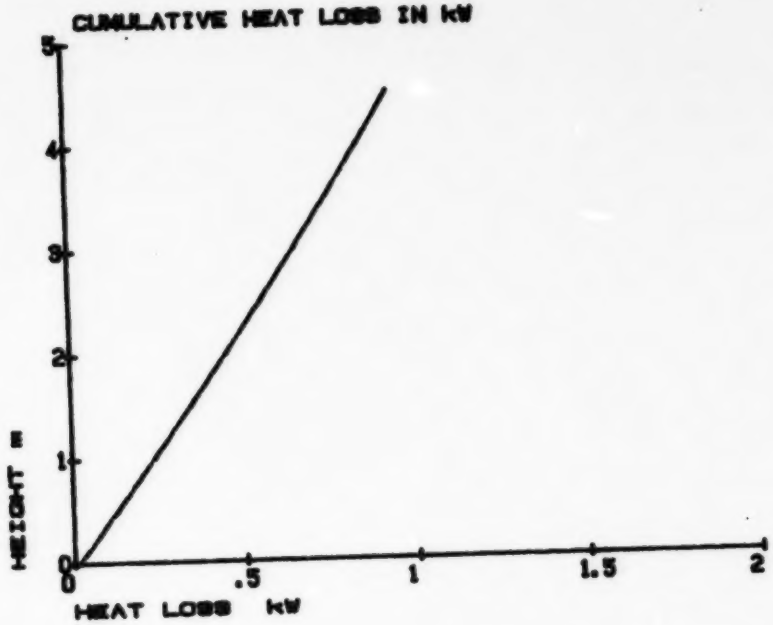


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	90202..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	159 C.
AVG. THERMAL CONDUCTIVITY	2.76 W/m2/C.
MASS FLOW RATE.	99 gm/s.
TOTAL HEAT LOSS.	905 WATTS.

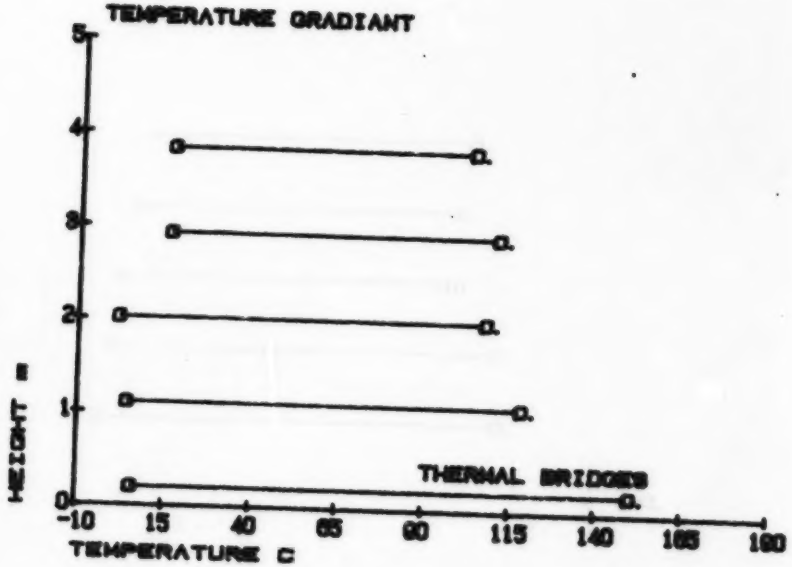


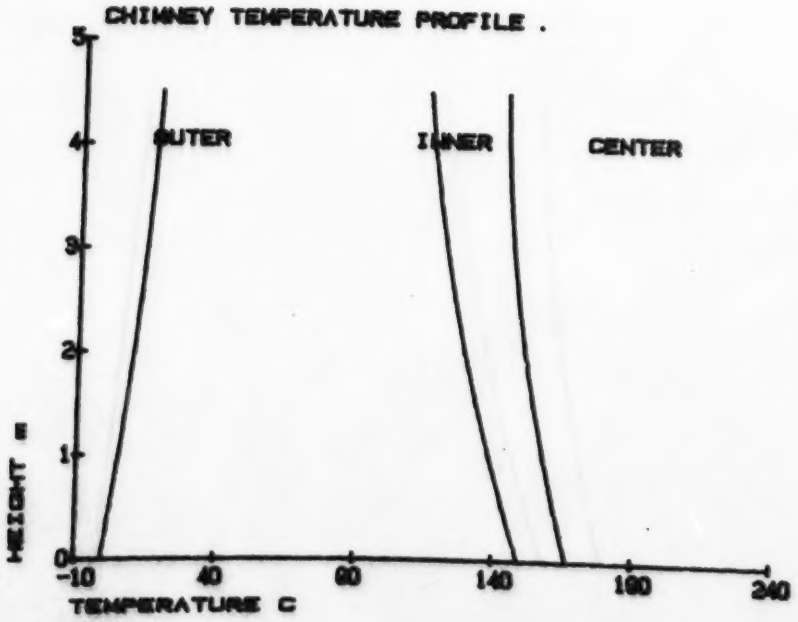


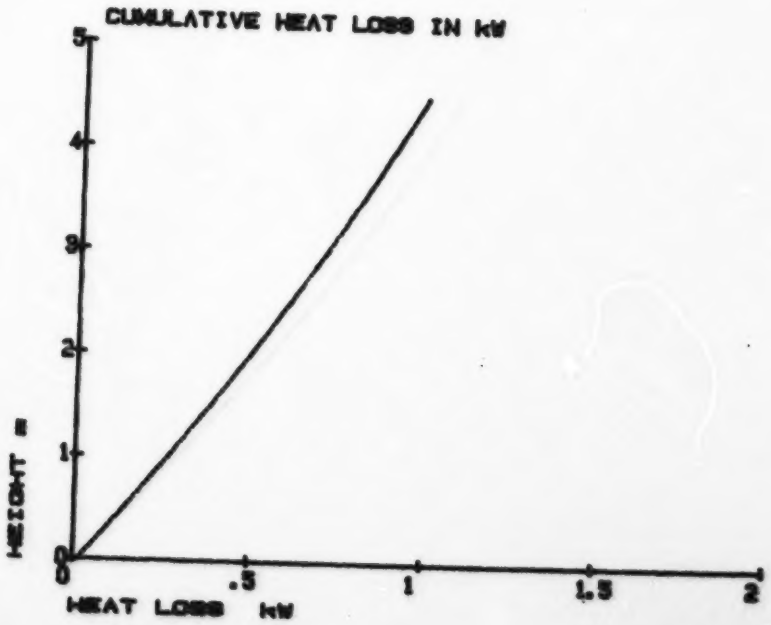


THERMAL PERFORMANCE CHARACTERISTICS.
OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	SOSOI..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	152 C.
AVG. THERMAL CONDUCTIVITY	8.86 W/m2/C.
MASS FLOW RATE:	89 gm/s.
TOTAL HEAT LOSS:	974 WATTS.

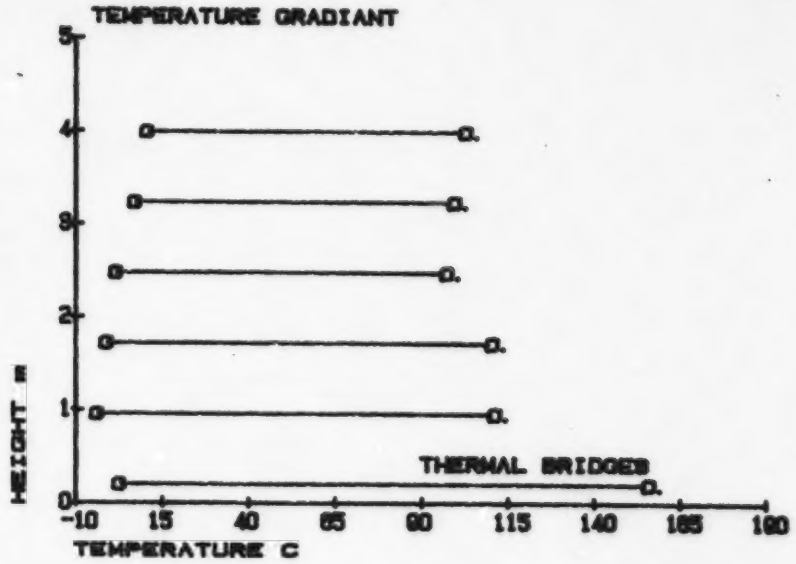


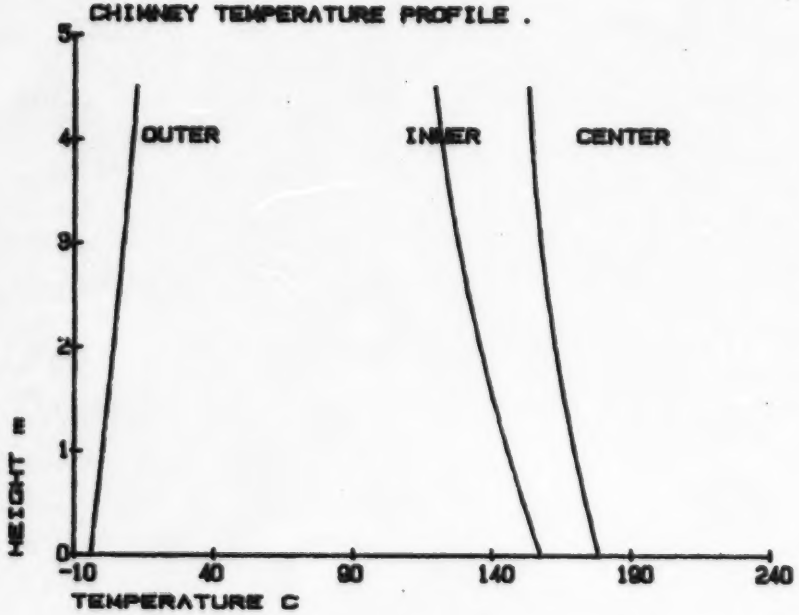


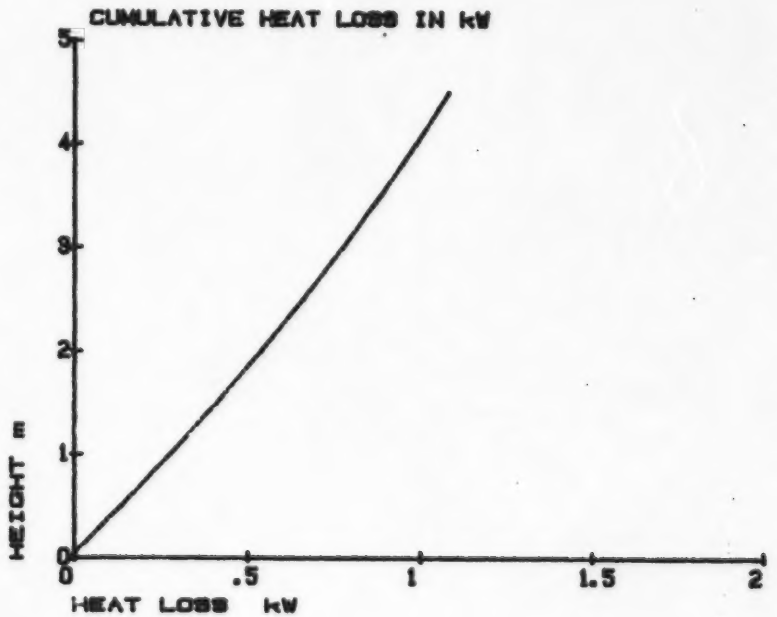


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90402..
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	167 C.
AVG. THERMAL CONDUCTIVITY	8.27 W/m2/C.
MASS FLOW RATE:	33 gm/s.
TOTAL HEAT LOSS:	1019 WATTS.

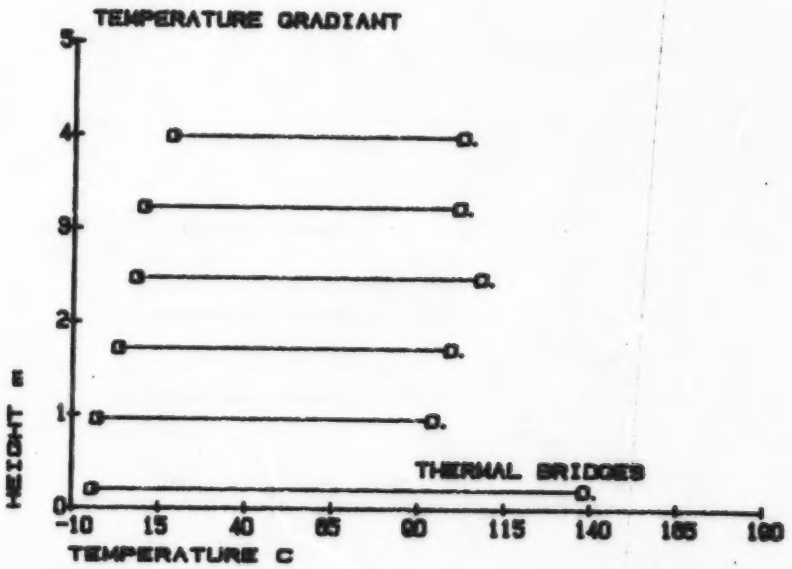


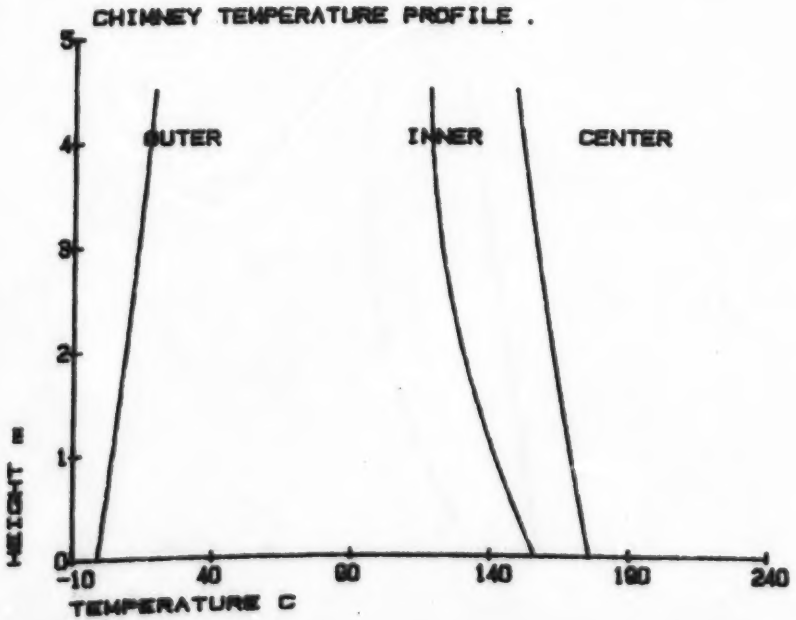


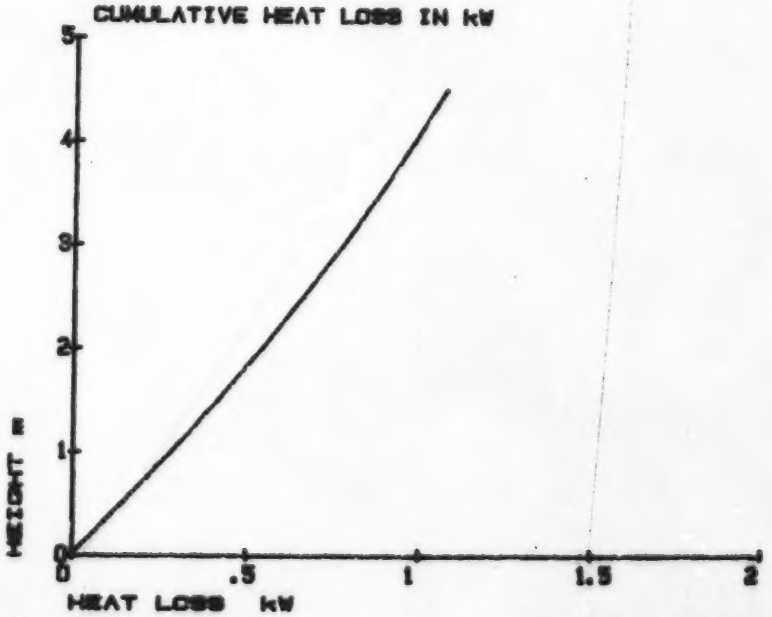


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90400.
CHIMNEY TYPE	A
AVG. TEMP. ACROSS WALL	182 C.
AVG. THERMAL CONDUCTIVITY	8.5 W/m2/C.
MASS FLOW RATE:	82 gm/s.
TOTAL HEAT LOSS:	1029 WATTS.

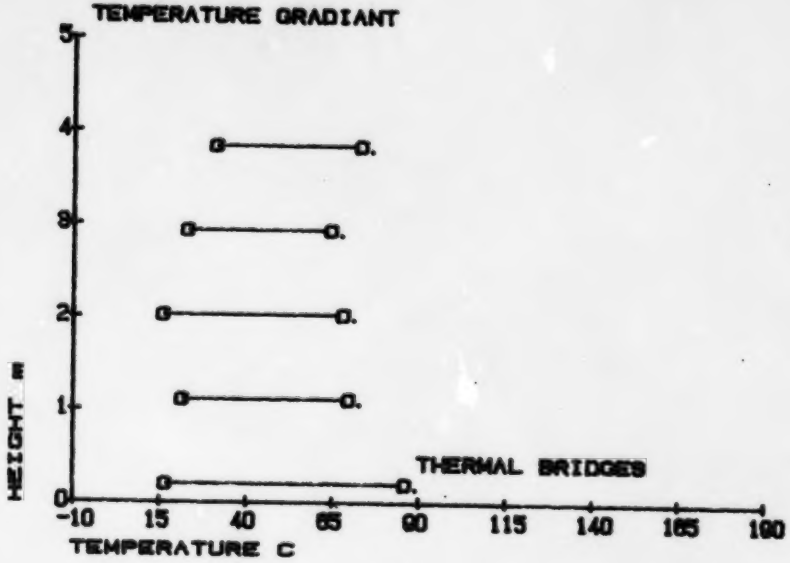


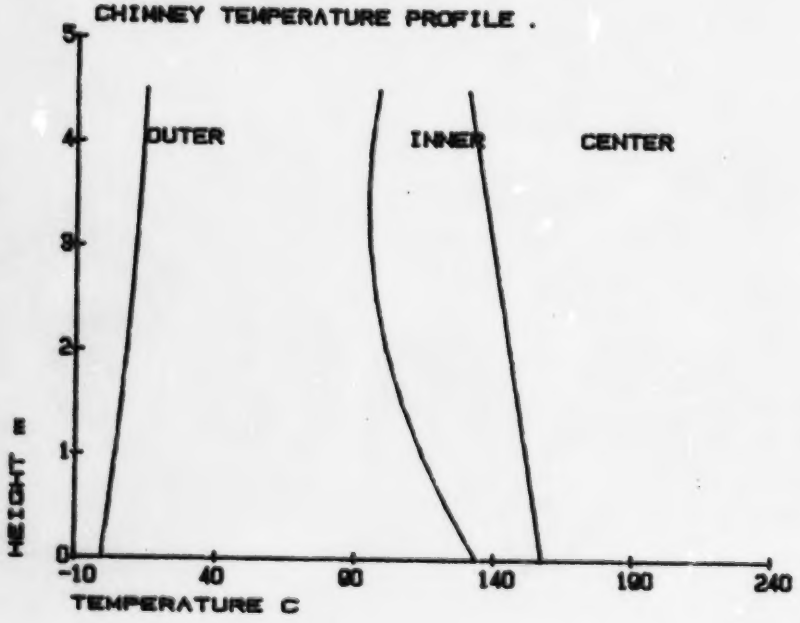


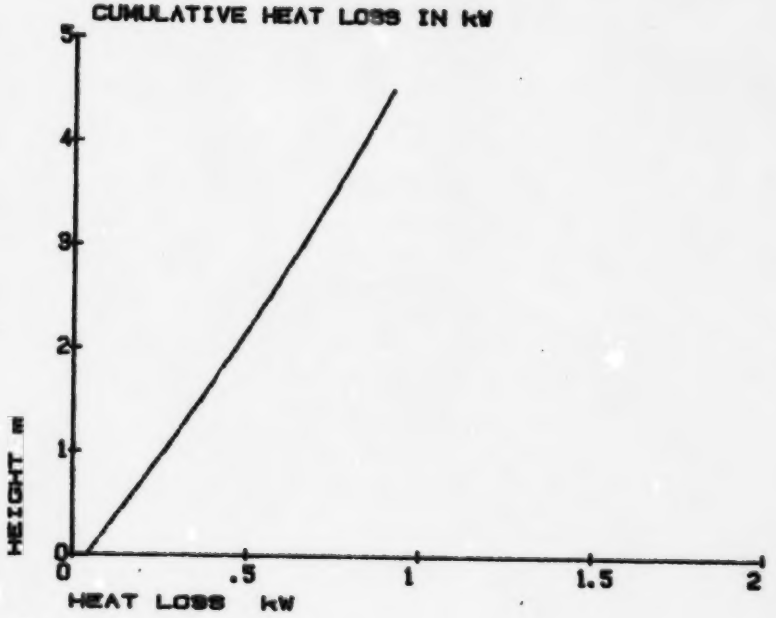


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90101..
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	145 C.
AVG. THERMAL CONDUCTIVITY	0.89 W/m2/C.
MASS FLOW RATE:	99 gm/s.
TOTAL HEAT LOSS:	856 WATTS.

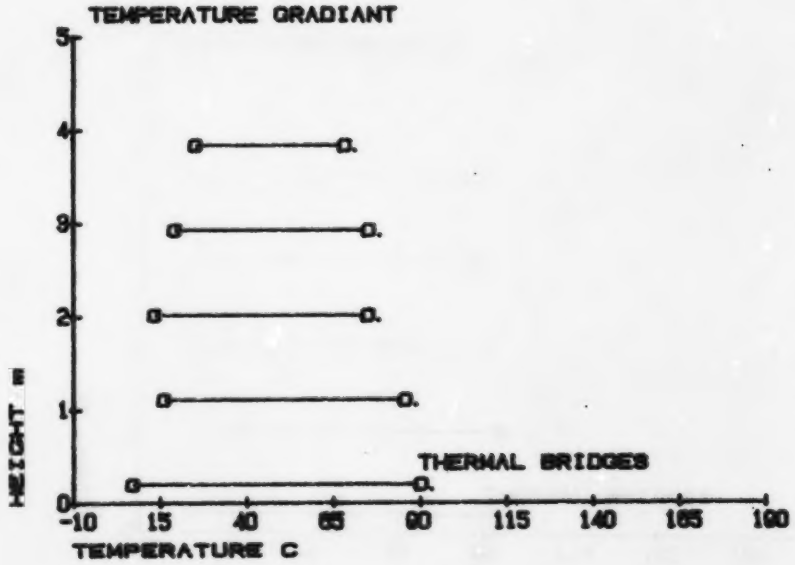


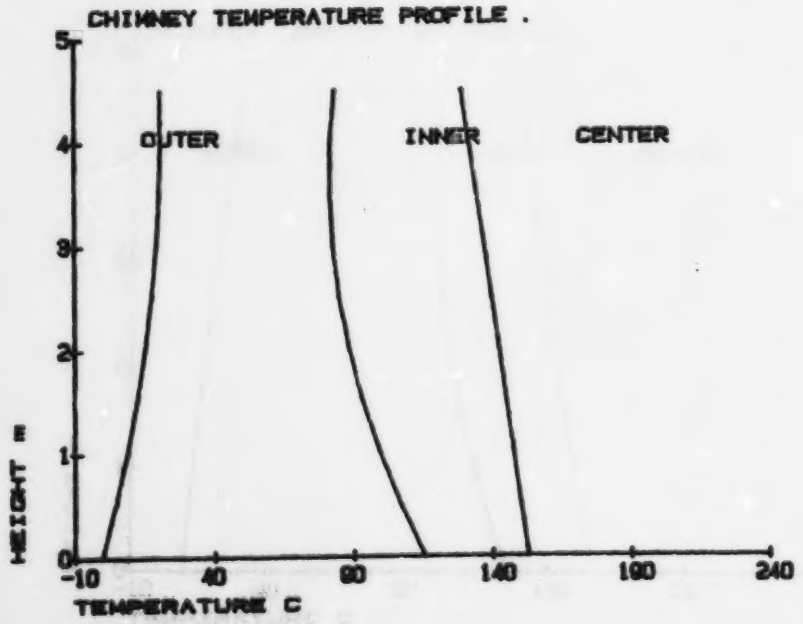


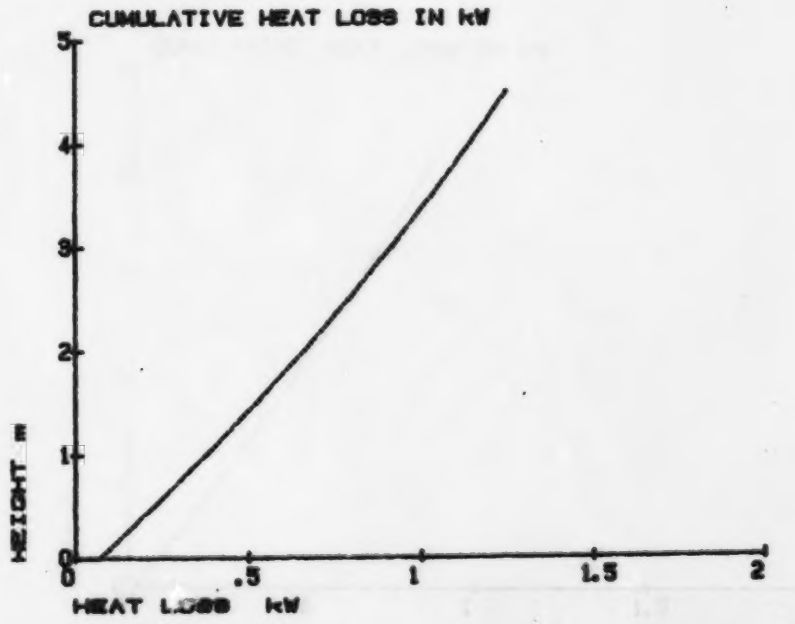


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	90501..
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	146 C.
AVG. THERMAL CONDUCTIVITY	6.55 W/m2/C.
MASS FLOW RATE.	34 gm/s.
TOTAL HEAT LOSS.	1218 WATTS.

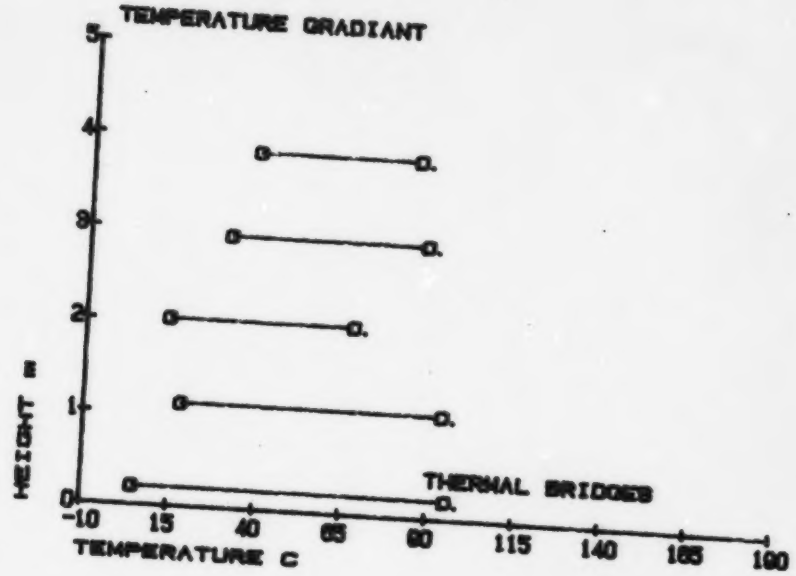


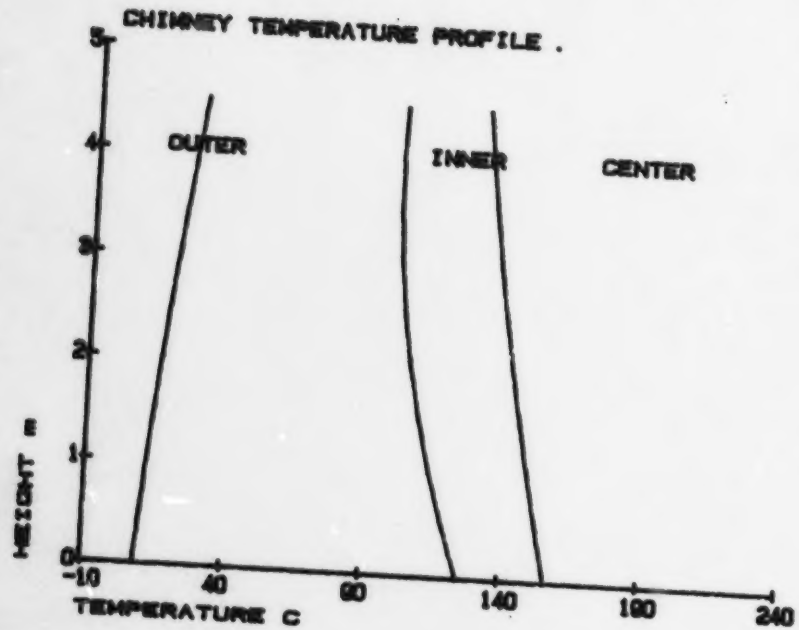


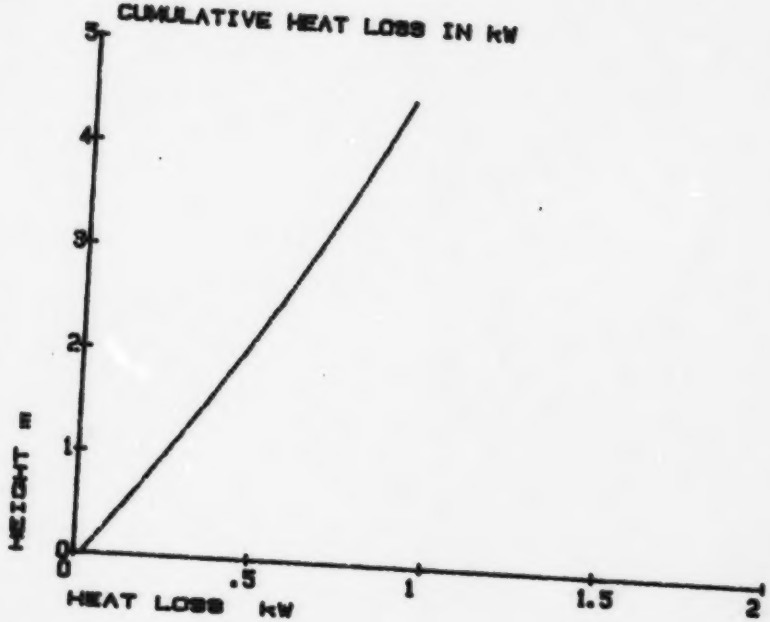


THERMAL PERFORMANCE CHARACTERISTICS.
OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90302..
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	142 C.
AVG. THERMAL CONDUCTIVITY	4.15 W/m2/C.
MASS FLOW RATE:	85 gm/s.
TOTAL HEAT LOSS:	894 WATTS.

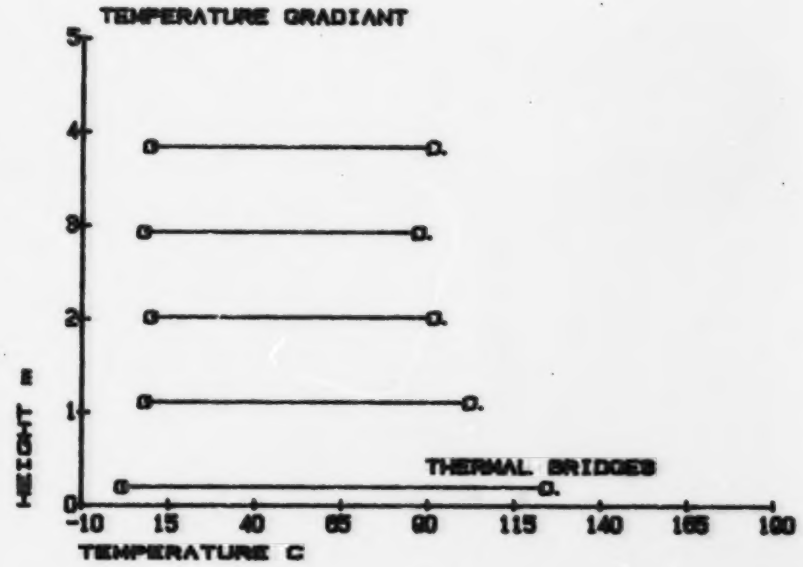


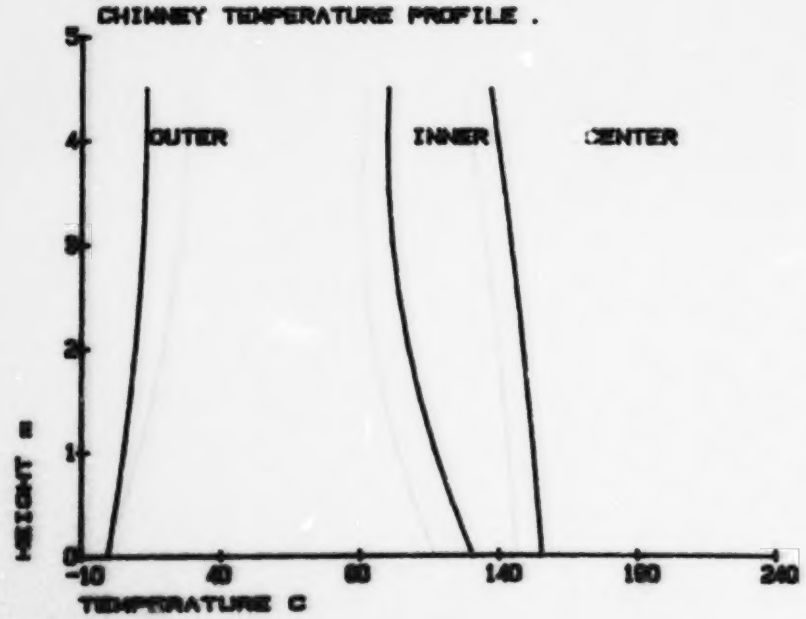


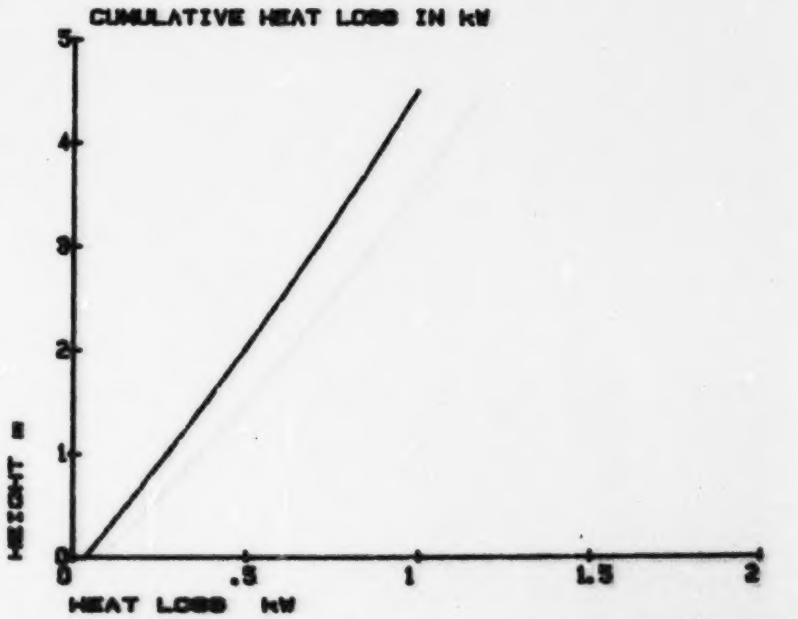


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	80702. .
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	145 C.
AVG. THERMAL CONDUCTIVITY	3.00 W/m2/C.
MASS FLOW RATE.	35 gm/s.
TOTAL HEAT LOSS.	981 WATTS.

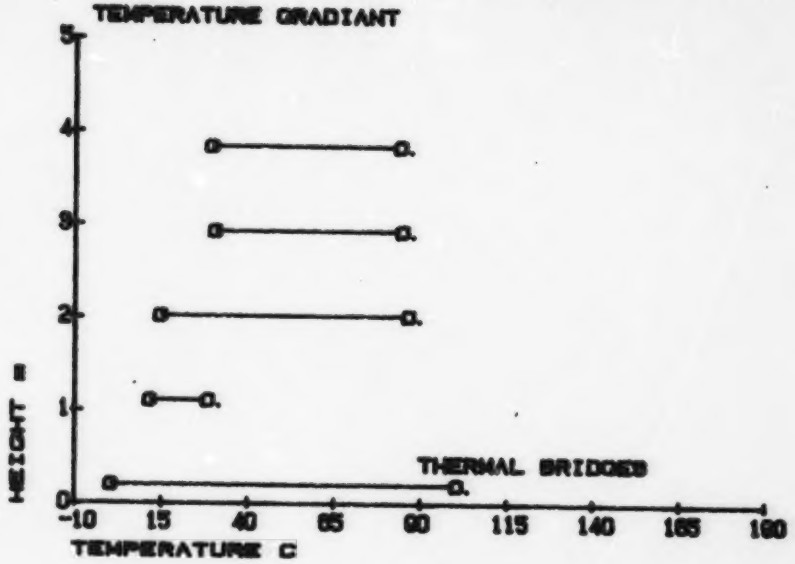


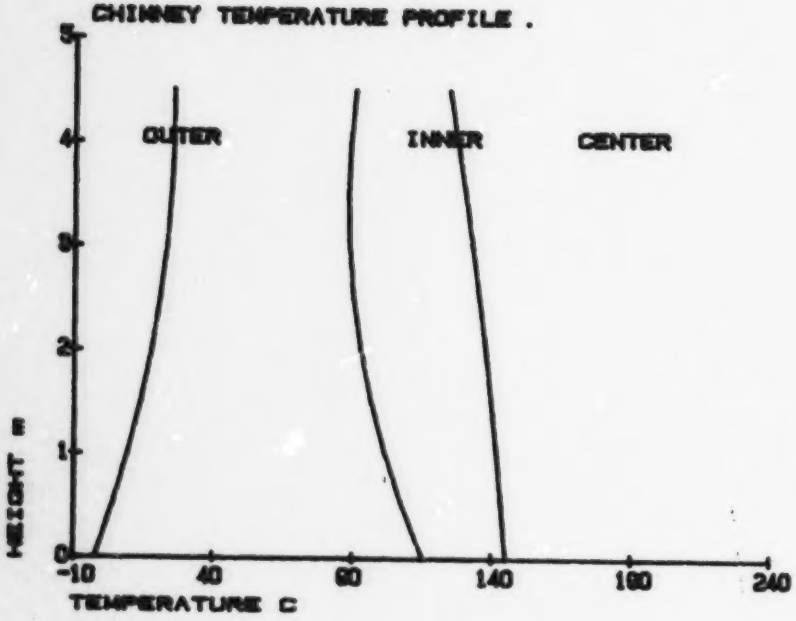


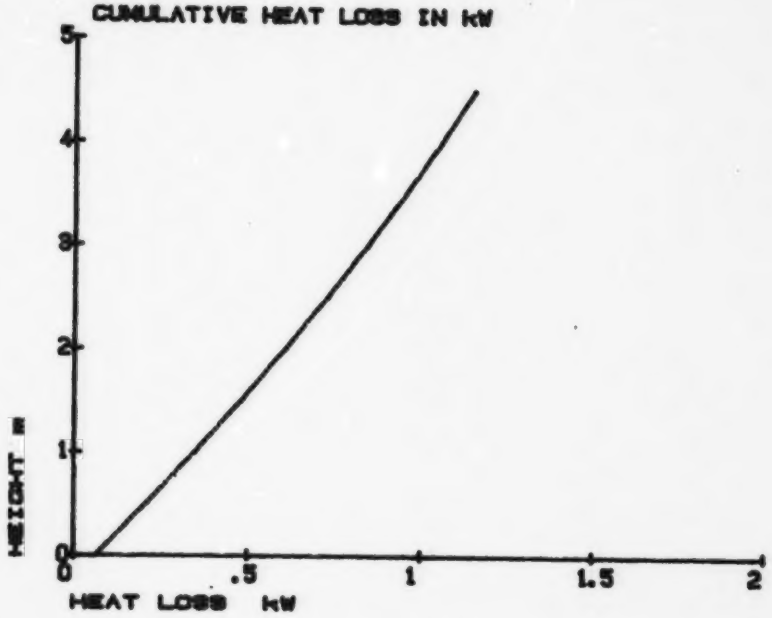


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE.	SOSO2..
CHIMNEY TYPE	S
AVG. TEMP. ACROSS WALL	141 C.
AVG. THERMAL CONDUCTIVITY	5.91 W/m2/C.
MASS FLOW RATE.	34 gm/s.
TOTAL HEAT LOSS.	1143 WATTS.

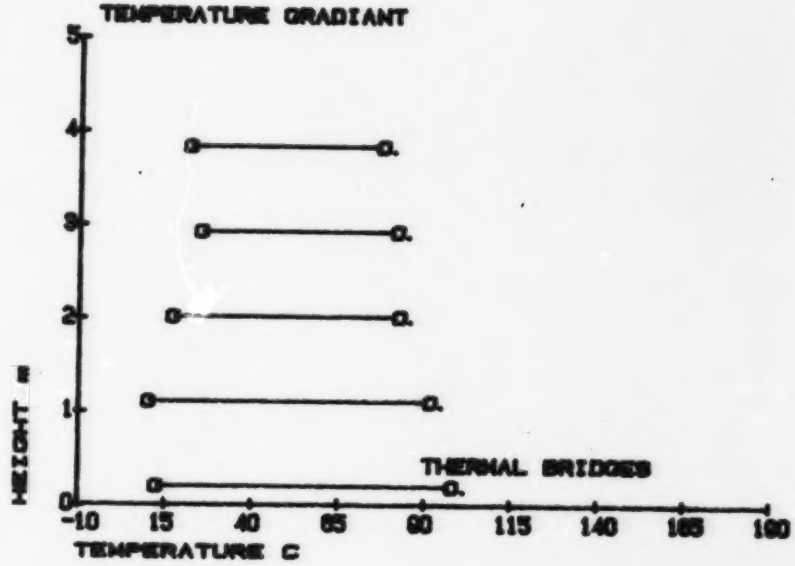


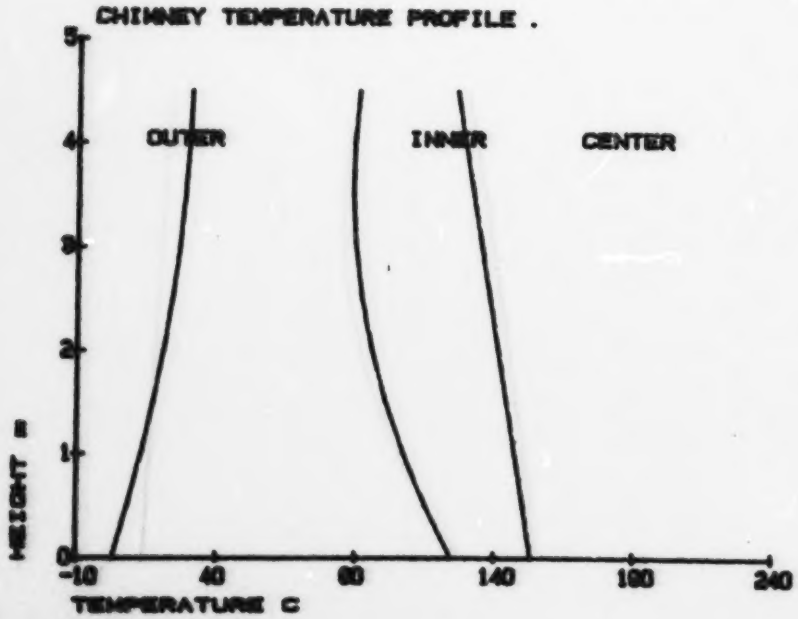


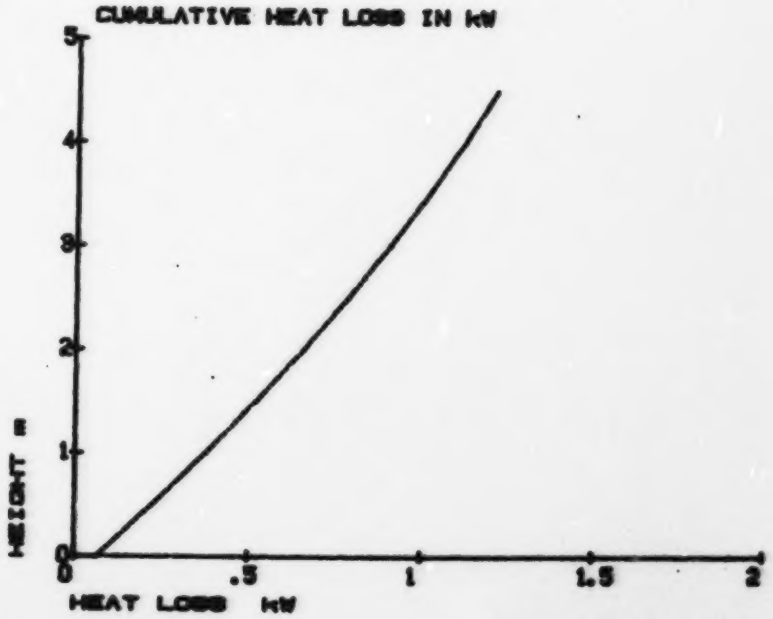


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90802.
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	140 C.
AVG. THERMAL CONDUCTIVITY	6.27 W/m2/C.
MASS FLOW RATE:	35 gm/s.
TOTAL HEAT LOSS:	1178 WATTS.

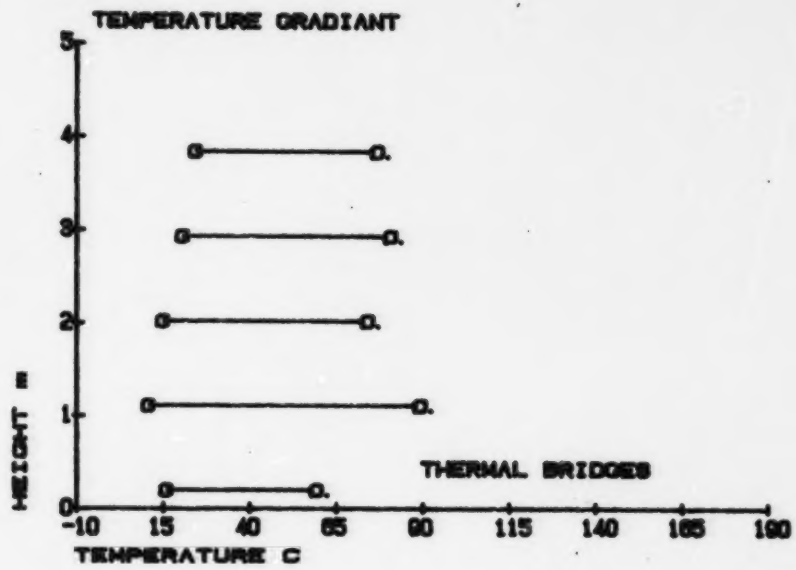


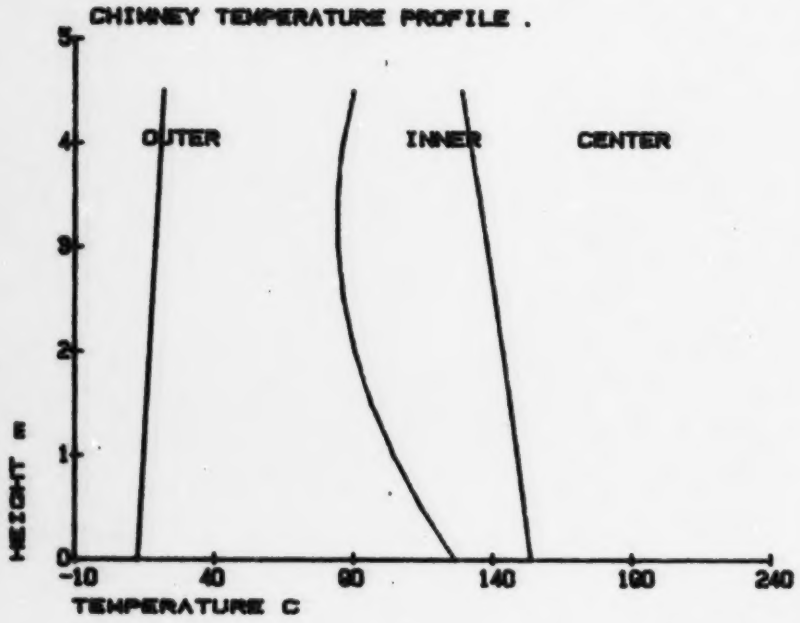


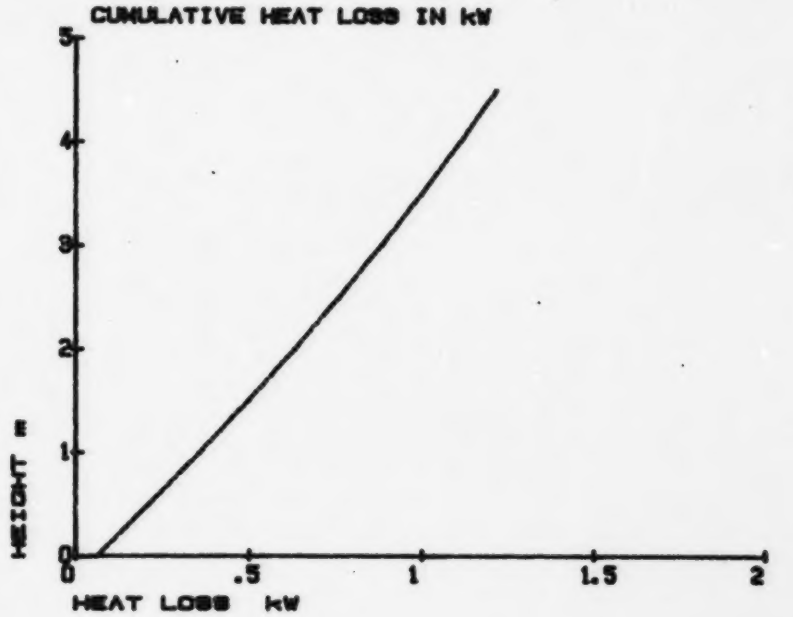


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90403.
CHIMNEY TYPE	B
AVG. TEMP. ACROSS WALL	144 C.
AVG. THERMAL CONDUCTIVITY	0.31 W/m2/C.
MASS FLOW RATE:	32 gm/s.
TOTAL HEAT LOSS:	1200 WATTS.

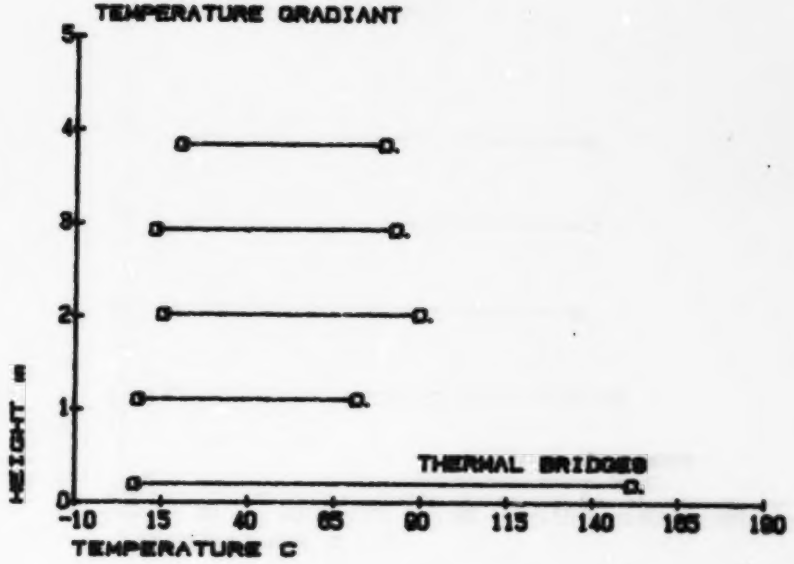


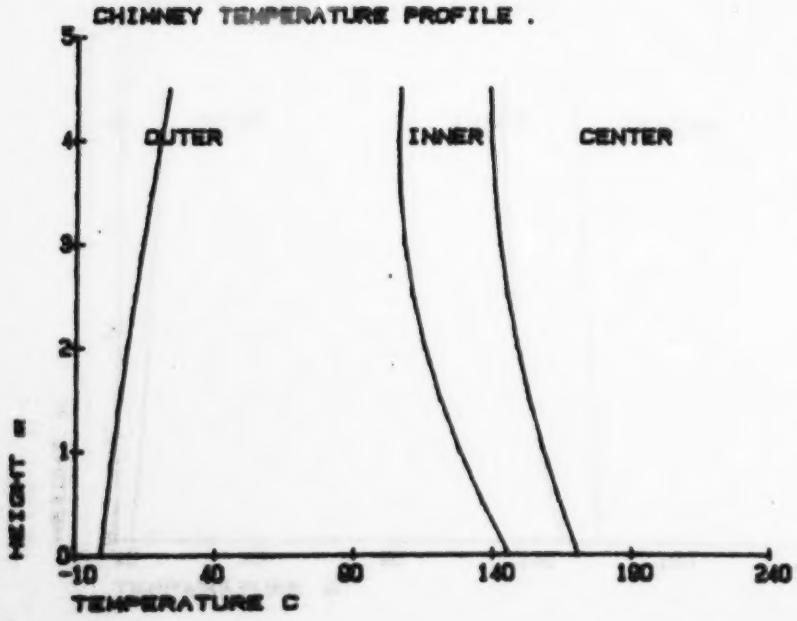


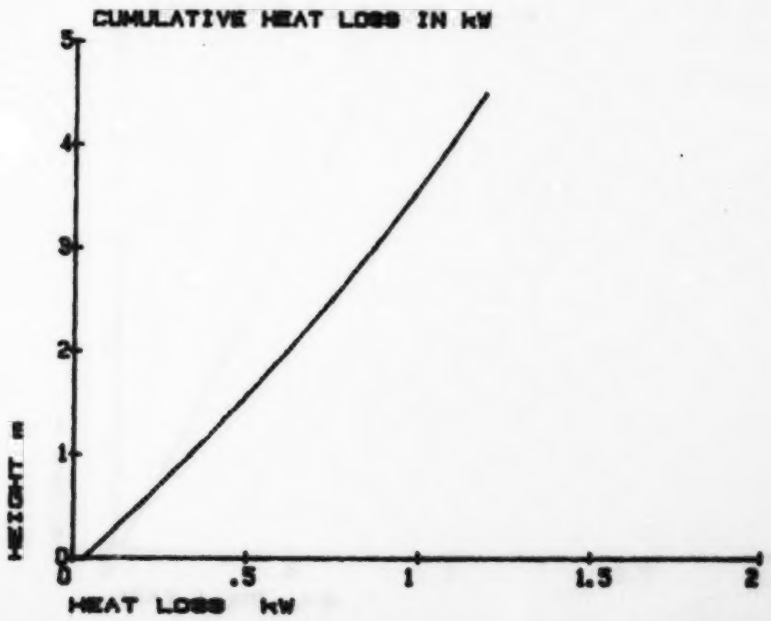


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	SOSCO. .
CHIMNEY TYPE	L
AVG. TEMP. ACROSS WALL	153 C.
AVG. THERMAL CONDUCTIVITY	4.44 W/m2/C.
MASS FLOW RATE:	41 gm/s.
TOTAL HEAT LOSS:	1133 WATTS.

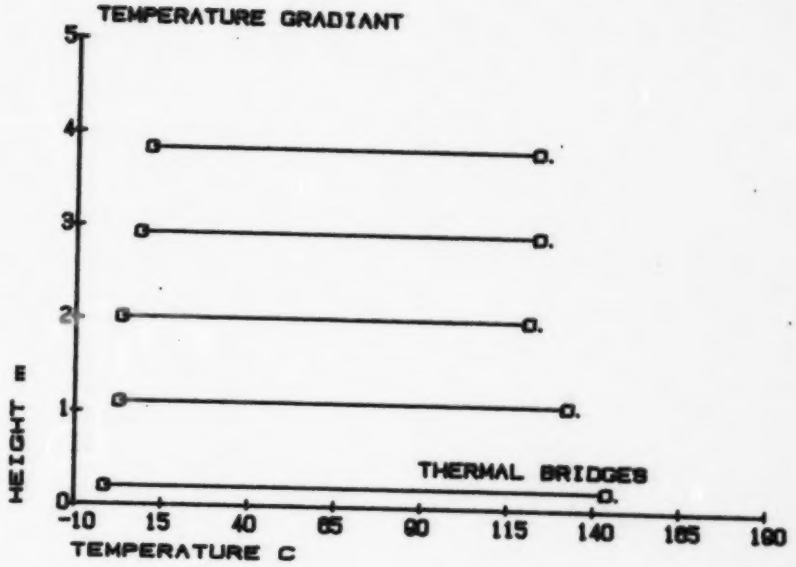


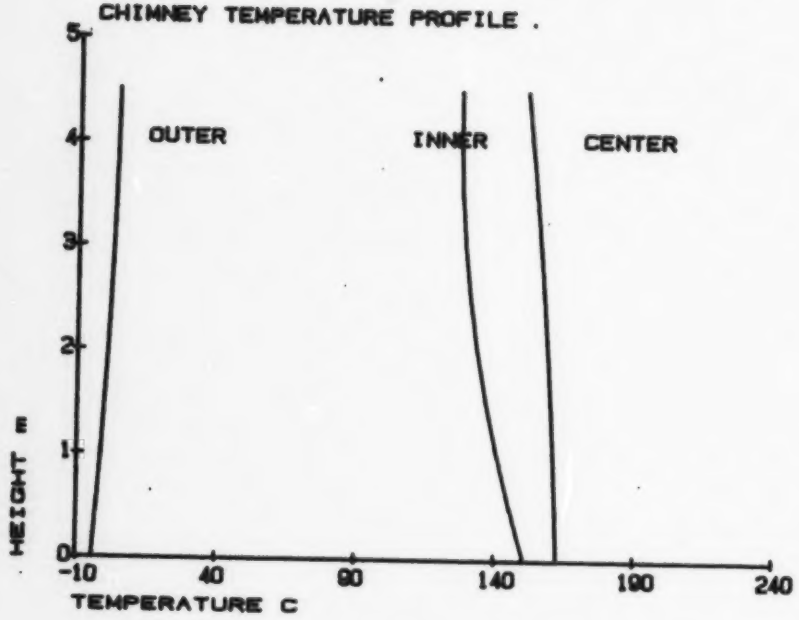


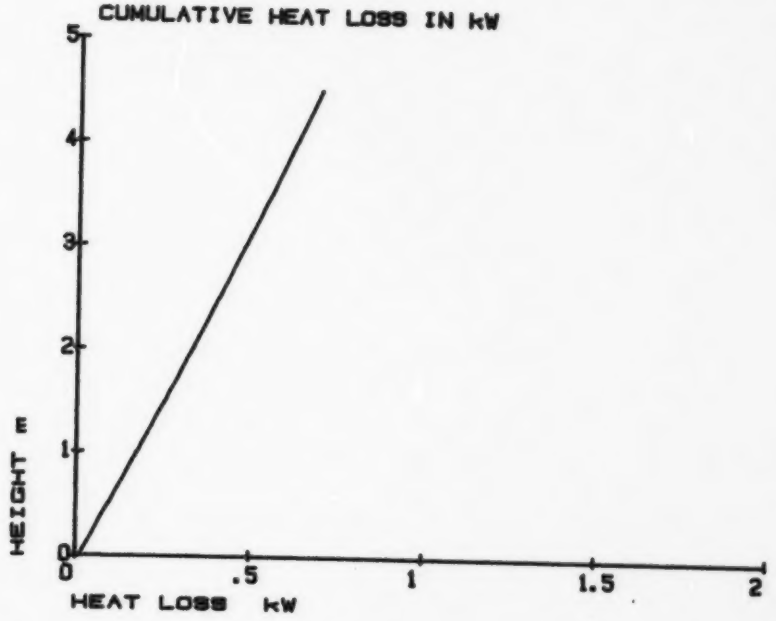


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90803..
CHIMNEY TYPE	850 STD
AVG. TEMP. ACROSS WALL	156 C.
AVG. THERMAL CONDUCTIVITY	2.1 W/m2/C.
MASS FLOW RATE:	85 gm/s.
TOTAL HEAT LOSS:	595 WATTS.

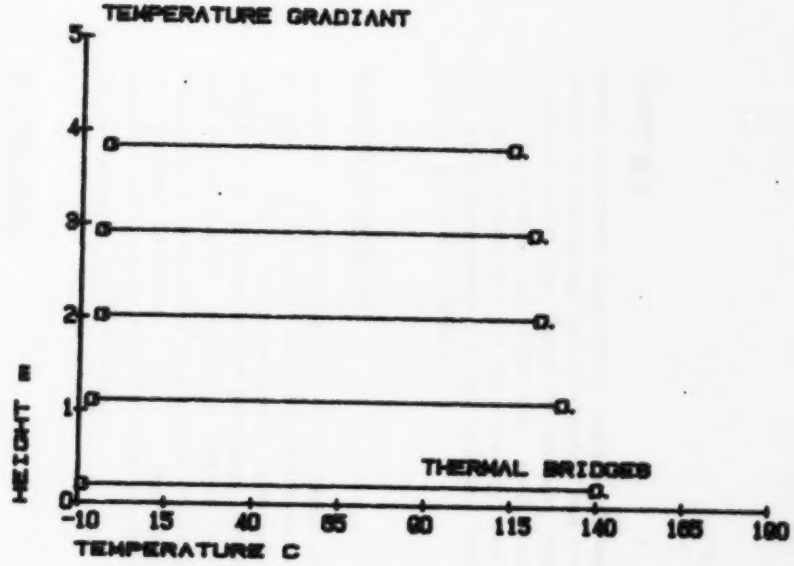


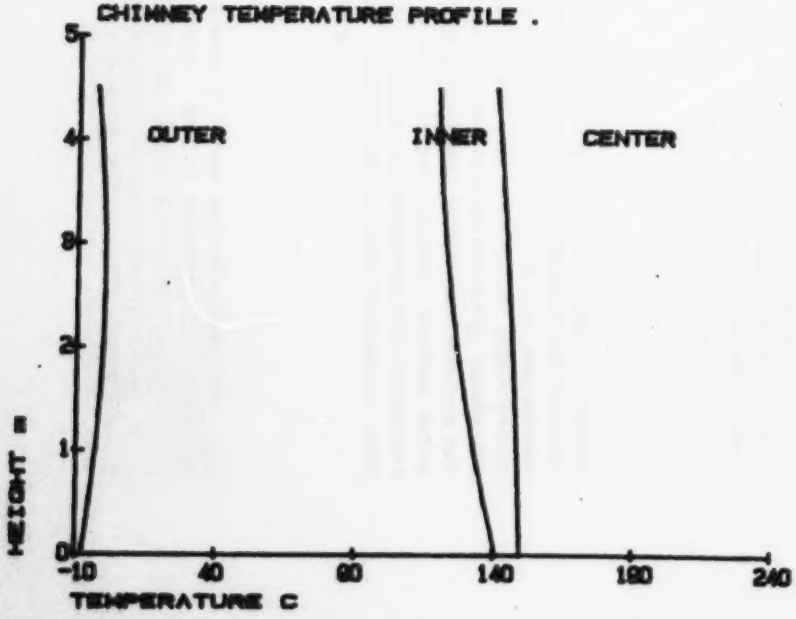


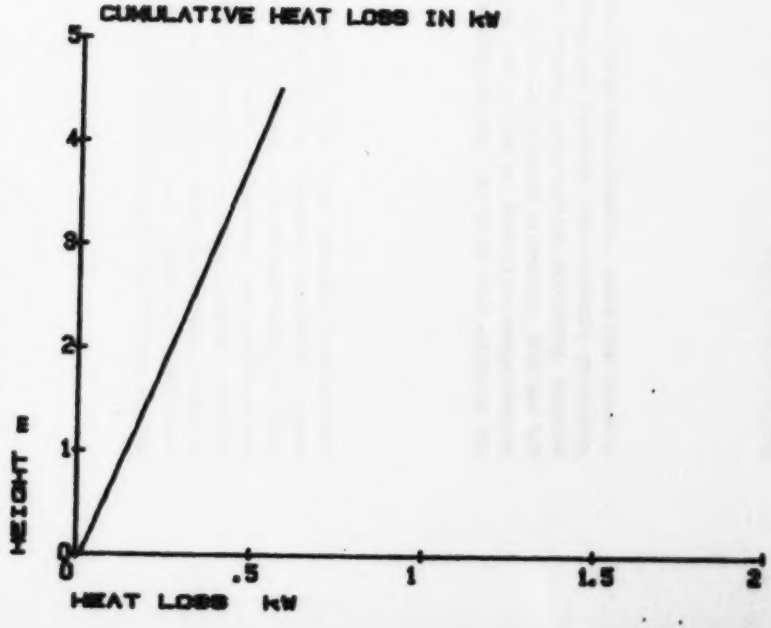


THERMAL PERFORMANCE CHARACTERISTICS. OF PRE-FABRICATED METAL CHIMNEYS

MANUFACTURE:	90404..
CHIMNEY TYPE	650 STD
AVG. TEMP. ACROSS WALL	148 C.
AVG. THERMAL CONDUCTIVITY	1.79 W/m2/C.
MASS FLOW RATE:	86 gm/s.
TOTAL HEAT LOSS:	578 WATTS.







ONTARIO**RESEARCH**
FOUNDATION

Energy

energy conservation programs and analyses, thermal insulation design and evaluation, waste heat recovery, building energy systems and monitoring, heat storage systems and materials, thermoelectric generation, combustion technology, burner development, heat transfer analysis, solar systems monitoring, National Solar Test Facility, solar technology, wind power, coal, lignite and oil sands processing, alternate fuel utilization, battery and fuel cell technology, peat processing and utilization, fenestration measurements, heat pump development and test facilities, residential heating systems, air to air heat exchange test facility, photovoltaic devices, . . .

Environment

ambient air quality assessment, environmental impact assessments, long-range transport of atmospheric pollutants, precipitation chemistry, particulate characterization studies, emission inventories, source sampling, odour emission and control, asbestos measurement and control, occupational health and safety studies, diesel emission control technology, air pollution control, pesticide residues, trace metal analysis, trace organic analysis, radionuclide analysis, mutagenic testing, noise and vibration analysis, radiation measurements, particulate identification and measurement, water surveys, water purification, industrial and municipal wastewater treatment, membrane separation techniques, wet oxidation, solid waste treatment and recovery, hazardous waste treatment and disposal, indoor air quality assessments, priority pollutant analysis, landfill technology, . . .

Materials

building materials, plastics, composites, metals, glass and ceramics, wood and wood composites, biomaterials, adhesives and printing inks, fibres, yarns, fabrics and geotextiles, leather, organic and inorganic chemicals, specification development, quality assurance, mechanical, chemical and thermal properties, test method development, failure analysis, fire and flammability, glass-metal seals, metal and alloy powders, metallography, materials characterization, materials characterization by optical and electron microscopy and X-ray microanalysis, photovoltaic materials, materials corrosion resource centre, corrosion properties and control, bacterial corrosion, coatings and sealants, rubber technology, X-ray analysis, cement and concrete, soils and aggregates, gypsum, body armour testing, footwear, paper-making materials, roofing and waterproofing, waste material stabilization and solidification, . . .

Products & Processes

clothing, footwear and industrial textile products, knitting technology, thin and thick film systems, microelectronics development, fibre optics, instrumentation, bioengineering, ultrasonic and fluid shear devices, microwave drying, transportation and equipment testing, mathematical stress and vibration analysis, product, equipment and machinery design & development, fuel emulsification, organic analysis and characterization, chemistry of foodstuffs, pulp and paper processes, ceramics processing, metallurgical process development, powder metal technology, packaging applications, technical and economic evaluations, industrial engineering applications, process control, enzyme analysis, electrical testing, radioactive surveys, industrial microbiology, biotechnology, technical and management skills development seminars, paper products, absorbent consumer products, detergent and cosmetic formulation, metal chemical analysis, flash hydropyrolysis of coal, electroplating, . . .

Resources

mineral processing, hydro and pyrometallurgical processing of ferrous and non-ferrous ores, coal evaluation, coal ash utilization and product development, asbestos processing and applications, non-metallic minerals/industrial minerals processing and utilization, uranium processing, forest utilization, utilization of forest and agricultural wastes, utilization of industrial, mining and domestic wastes, energy and chemicals from biomass, in-plant waste reduction, mineralogical services, mining and metallurgical waste disposal, . . .

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